SENSITIVITY ANALYSIS of TreeBLOSSIM: PhotoMARVL TREES from Experiment CY597 (Eyrewell)

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EXECUTIVE SUMMARY

TreeBLOSSIM is a linked individual tree and branch growth model that was developed to project mid-rotation inventory data forward in time. The branching data required to develop the model was obtained through detailed destructive sampling of a few trees. In this study, non-destructive sampling using PhotoMARVL was used to determine how well TreeBLOSSIM performed for a range of silvicultural treatments in the Eyrewell replicate of the 1975 final crop stocking trial.

Five trees were PhotoMARVLed from each of 7 silvicultural treatments giving a total of 35 trees. The data from the PhotoMARVL images were compared with predictions from TreeBLOSSIM.

TreeBLOSSIM tended to overpredict tree DBH. The error was between 7 cm and 15 cm for 7 trees. These trees were at the 10^{th} or 40^{th} percentile position in the plot DBH distribution.

Each stem was divided into 2 zones, less than or equal to 9 m and greater than 9 m. Zone mean values for the diameter of the largest branch in a cluster were calculated. If the TreeBLOSSIM mean was within 2cm of the PhotoMARVL mean, then the model prediction was considered acceptable. Using this criterion, TreeBLOSSIM predictions were acceptable for all but 3 of the 70 zones. The TreeBLOSSIM prediction of the zone variance for the diameter of the largest branch in a cluster tended to be larger than observed.

Below 9 m, TreeBLOSSIM predictions of the number of branch clusters were reasonable. Above 9 m, TreeBLOSSIM predicted between 0.6 and 1.2 more branch clusters per metre than observed.

SENSITIVITY ANALYSIS of TreeBLOSSIM:
PhotoMARVL TREES from Experiment CY597 (Eyrewell)

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INTRODUCTION

TreeBLOSSIM is a linked individual tree and branch growth model that was developed to project mid-rotation inventory data forward in time. The branching data required to develop the model was obtained through detailed destructive sampling of a few trees. Non-destructive sampling using PhotoMARVL is considered to be an appropriate method to determine how well the model performs for a wider range of sites and silvicultural treatments.

In order to test how well TreeBLOSSIM predicts branch response to different silvicultural treatments, PhotoMARVL images were collected in the 4 final crop-stocking trials planted in 1975. The data are documented in the following reports:

- Kaingaroa, RO2098 - SGMC Reports 93 and 99
- Eyrewell, CY597 - SGMC Report 104
- Woodhill, AK1056 - SGMC Report 112
- Golden Downs, NN529/1 - SGMC Report 112

TreeBLOSSIM was run using the associated permanent sample plot (PSP) tree size data and the predictions compared with PhotoMARVL data. The comparisons are documented in the following reports:

- Kaingaroa, RO2098 - SGMC Report 110
- Eyrewell , CY597 - This report
- Woodhill, AK1056 - SGMC Report 116
- Golden Downs, NN529/1 - SGMC Report 116

METHODS

<u>Sample Plot Selection</u>

The final crop stocking trials were planted in 1975 as an “850” polycross trial with an initial stocking of 625 stems/ha. Permanent sample plots (PSPs) for the final crop stocking trial were established in 1986. There were 7 treatments:
- an unthinned control (6 replicates),
- six different thinning treatments (3 replicates of each treatment).

At all 4 sites, one sample plot per treatment was selected. This was the plot where:
- the initial stocking and final stocking were closest to the prescribed treatment
- there was minimal mortality.

The sample plots selected at Eyrewell are shown in Table 1.

Table 1. Experiment CY597: treatments and plots examined.

Treatment	Plot examined
Unthinned	13/24
Thinned to 100sph at age 11 yrs	15/21
Thinned to 200sph at age 11 yrs	9/22
Thinned to 400sph at age 11 yrs	10/23
Thinned to 100sph at age 14 yrs	14/25
Thinned to 200sph at age 14 yrs	11/26
Thinned to 400sph at age 14 yrs	12/27

<u>Selection of PhotoMARVL trees</u>

For each selected plot, the trees present at the last (July 1999) PSP re-measurement were ranked according to the diameter at breast height (DBH), and their percentage rank calculated. Undamaged trees whose rank was closest 10^{th}, 40^{th}, 70^{th}, 90^{th}, and 100^{th} percentile were selected to be PhotoMARVLed.

In the office, the following measurements were extracted from the photograph for each branch cluster using the AP190 analytical stereo plotter (Firth *et. al*, 2000):

- stem diameter below the cluster,
- height to base and top of the cluster,
- diameter of the largest branch in the cluster that was visible on the photograph.

At this site it was difficult to measure branch diameter high in the stem. On 13 trees it was not possible to measure branch diameters above 16 m and it was only possible to measure branch diameters above 20 m on 3 trees (see Table 2).

Table 2. Height of highest branch measured for diameter from PhotoMARVL images.

	Number of trees where height of highest branch measured falls between:		
Plot /Treatment	**12-16 m**	**16-20 m**	**> 20 m**
13/24 (unthinned)	3	2	0
15/21 (100 / 11)	1	4	0
9/22 (200 / 11)	2	3	0
10/23 (400 / 11)	3	2	0
14/25 (100 / 14)	0	4	1
11/26 (200 / 14)	1	2	2
12/27 (400 / 14)	3	2	0

<u>TreeBLOSSIM simulations</u>

For each selected sample plot, the PSP measurements at age 14 years (after all silviculture had been completed) were imported into TreeBLOSSIM (Version 2.0x (23.5.2003)). This version only differs from Versions 1.1 and 1.2 (used in previous comparisons) in that minor programming errors have been fixed. The model is described in SGMC Report No. 113 and the model functions in SGMC Report No. 108.

TreeBLOSSIM first calculated the position and size of all branches at age 14 years (including the effects of any previous silviculture). The stems and branches were then grown forward to age 26 years, the age at which the PhotoMARVL images were collected.

The model was set so that there was no tree mortality, a realistic assumption given the way the sample plots were selected. The resulting branch data file was exported from TreeBLOSSIM and imported into a SAS program that synthesised the data generated to the following variables for each PhotoMARVL tree:

- tree diameter at breast height
- cluster height and diameter of largest branch in each cluster.

Comparisons

Difference between field-measured (with a tape at time of PhotoMARVL) and predicted diameter at breast height (DBH) was calculated and compared with predicted DBH.

Graphs of diameter of the largest branch in a cluster (both model prediction and PhotoMARVL estimate) were plotted against cluster height.

The stem was split into two zones based on a visual assessment of the graphs in SGMC Report 104:

- Zone 1: less than or equal to 9 m, where pre-thinning stocking would have most influence on branch diameter,
- Zone 2: greater than 9 m, where branch diameters were likely to have been influenced by the thinning treatment and post-thinning stocking.

For each zone, the mean branch diameter (averaged over the largest branch in each cluster) was calculated for both the model predictions and PhotoMARVL estimates. The difference between the two means was calculated. If the difference was less than 2 cm, then the model was deemed acceptable for that zone.

To compare the variability in the diameter of the largest branch in a cluster, the variance in each zone was calculated for both the PhotoMARVL data and TreeBLOSSIM predictions. The ratio was compared using an F test.

For each zone, the number of branch clusters was calculated for both the model prediction and PhotoMARVL assessment.

RESULTS

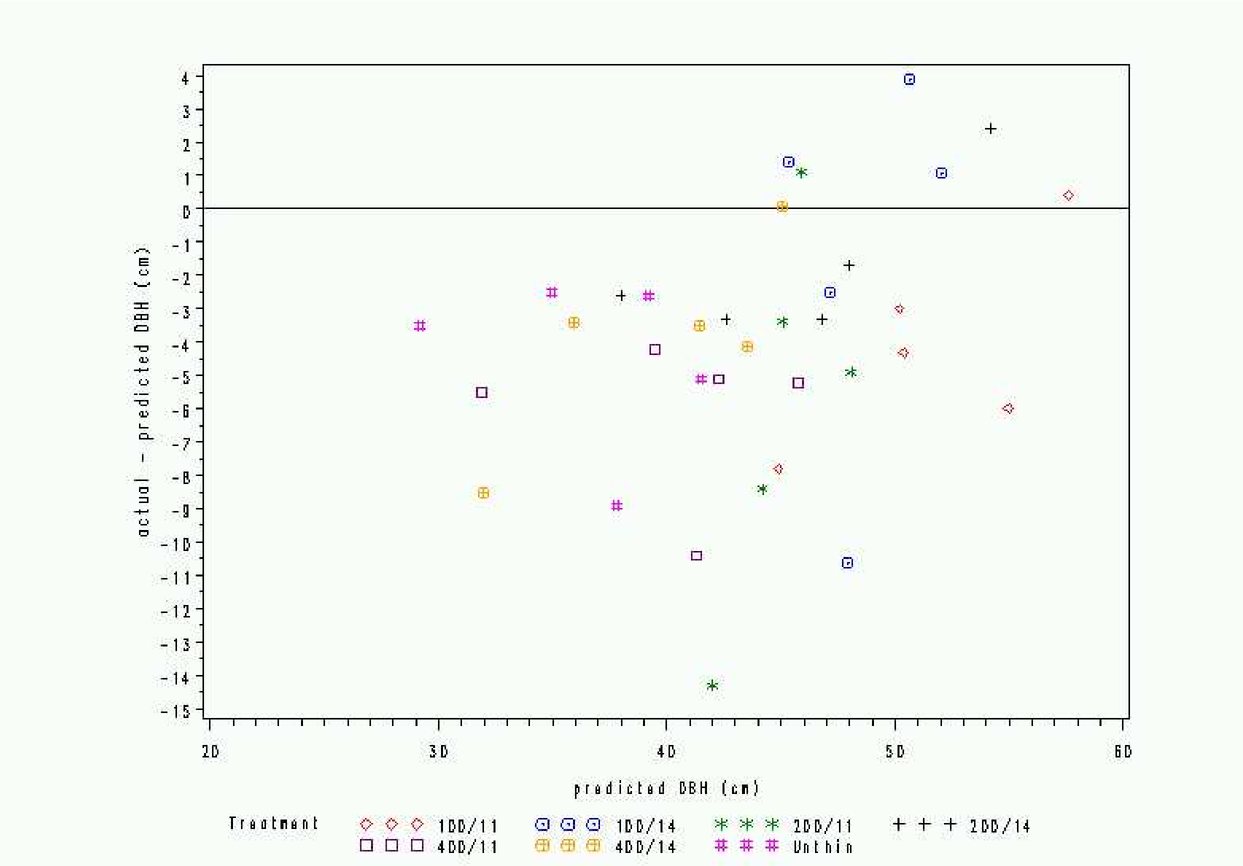
Tree DBH

Actual and predicted DBH at age 26 years are shown in Table 3. TreeBLOSSIM predictions of tree DBH tended to be larger than the field measurements (Figure 1). There were 7 trees where the difference was over 7 cm. These were all trees at 10 or 40 percentile in the DBH distribution.

Table 3. CY597 - Actual and predicted (after 12 year increment period) tree DBH at age 26 years

Plot	Treatment: Final Crop Stocking/ Age at thinning	Position in DBH distribution	Tree Number (PSP)	Tree Number: TreeBLOSSIM	Measured DBH With tape (Age 26 years)	Predicted DBH (Age 26 years)
9/22	200/11	10%	2/26	42	27.7	42.0
		40%	3/40	48	35.8	44.2
		70%	1/7	34	41.7	45.1
		90%	4/46	51	47.0	45.9
		100%	2/23	40	43.2	48.1
10/23	400/11	10%	0/28	6	26.4	31.9
		40%	3/20	22	30.9	41.3
		70%	3/18	20	35.3	39.5
		90%	2/16	18	37.2	42.3
		100%	3/22	24	40.6	45.8
11/26	200/14	10%	0/7	5	35.4	38.0
		40%	0/31	23	39.3	42.6
		70%	3/33	44	43.5	46.8
		90%	1/6	36	46.3	48.0
		100%	0/38	27	56.6	54.2
12/27	400/14	10%	3/13	15	23.5	32.0
		40%	1/4	8	32.6	36.0
		70%	0/9	1	38.0	41.5
		90%	0/12	2	39.5	43.6
		100%	4/18	20	45.2	45.1
13/24	Unthinned	10%	2/12	12	25.7	29.2
		40%	1/6	6	28.9	37.8
		70%	3/14	14	32.5	35.0
		90%	1/3	3	36.4	41.5
		100%	1/1	1	36.6	39.2
14/25	100/14	10%	9/2	47	37.4	48.0
		40%	4/5	22	44.7	47.2
		70%	9/4	49	46.8	45.4
		90%	15/6	81	53.2	52.1
		100%	6/5	34	54.6	50.7
15/21	100/11	10%	11/5	59	37.1	44.9
		40%	15/3	80	46.1	50.4
		70%	19/1	101	47.2	50.2
		90%	9/1	45	49.0	55.0
		100%	16/5	88	58.0	57.6

Figure 1. Difference between PhotoMARVL measurement and TreeBLOSSIM estimate of DBH.



Branch diameter - mean

Graphs of diameter of the largest branch in a cluster (both TreeBLOSSIM predictions and PhotoMARVL measurements) versus cluster height are shown in Appendix 1, Figures 2-36). A visual examination of these graphs indicated that TreeBLOSSIM trends were reasonable but that TreeBLOSSIM predicted a larger than observed variation for the diameter of the largest branch in a cluster.

To compare predicted branch diameters with PhotoMARVL measurements, the stem of each tree was split into 2 zones. For each zone, the mean branch diameter (averaged over the largest branch in each cluster) was calculated for both TreeBLOSSIM predictions and PhotoMARVL estimates. The difference between the two means was calculated. If the difference was less than 2 cm, then the model was deemed acceptable for that zone. These results are summarised in 2 ways:

1. The number of zones within a tree for which TreeBLOSSIM predictions were acceptable are shown in Table 4.
2. The percentage of trees for which TreeBLOSSIM predictions were acceptable in a given zone is shown in Table 5.

Table 4. Number of zones within a tree where difference between TreeBLOSSIM and PhotoMARVL estimate of mean branch diameter (averaged over the largest branch in each cluster) is within 2cm.

Plot / Treatment	Tree at 10th percentile (Number of zones)	Tree at 40th percentile (Number of zones)	Tree at 70th percentile (Number of zones)	Tree at 90th percentile (Number of zones)	Tree at 100th Percentile (Number of zones)
13/24 (unthinned)	2	2	2	2	2
15/21 (100 / 11)	2	2	2	2	2
9/22 (200 / 11)	2	2	2	2	2
10/23 (400 / 11)	2	2	2	1	1
14/25 (100 / 14)	2	2	1	2	2
11/26 (200 / 14)	2	2	2	2	2
12/27 (400 / 14)	2	2	2	2	2

Table 5. Percentage of trees where difference between TreeBLOSSIM and PhotoMARVL estimate of mean branch diameter (averaged over the largest branch in each cluster) is within 2cm for a given zone.

Plot / Treatment	**Zone 1 % of trees**	**Zone 2 % of trees**
13/24 (unthinned)	100%	100%
15/21 (100 / 11)	100%	100%
9/22 (200 / 11)	100%	100%
10/23 (400 / 11)	60%	100%
14/25 (100 / 14)	100%	80%
11/26 (200 / 14)	100%	100%
12/27 (400 / 14)	100%	100%

Branch diameter – variance

The variance for the diameter of the largest branch in a cluster was calculated for each zone for both the PhotoMARVL data and TreeBLOSSIM predictions. The ratio was compared using an F test (Table 6). TreeBLOSSIM variance was significantly greater than the PhotoMARVL variance for 2 to 6 zones (out of 10) per plot. TreeBLOSSIM predicted several clusters with very small branches. Such clusters were extremely rare in the PhotoMARVL data.
Where the PhotoMARVL variance was significantly greater than the TreeBLOSSIM variance, extra large branches had been observed in the PhotoMARVL image.

Table 6. Comparison of variance for diameter of the largest branch in a cluster between PhotoMARVL and TreeBLOSSIM.

Plot / Treatment	Number of zones (out of 10) where TreeBLOSSIM variance is significantly greater than PhotoMARVL variance	Number of zones (out of 10) where TreeBLOSSIM and PhotoMARVL variances are not significantly different	Number of zones (out of 10) where PhotoMARVL variance is significantly greater than TreeBLOSSIM variance
13/24 (unthinned)	4	5	1
15/21 (100 / 11)	2	8	0
9/22 (200 / 11)	4	6	0
10/23 (400 / 11)	6	3	1
14/25 (100 / 14)	3	6	1
11/26 (200 / 14)	4	5	1
12/27 (400 / 14)	3	7	0

Number of branch clusters

Plot mean values, for the difference between TreeBLOSSIM estimate and PhotoMARVL measurement of the number of branch clusters per metre in each zone are shown in Table 7. In the lower zone (Zone 1 - less than or equal to 9 m), the differences were small. In the upper zone (Zone 2 – above 9 m) TreeBLOSSIM predicted more clusters than were observed on the PhotoMARVL image. It is known to be difficult to pick up very small branch clusters on the photographic image, and some portion of the error is likely to be from this source. It is not known whether this accounts for all the error or whether the model is predicting too many branch clusters higher in the tree.

Table 7. Plot mean values for the difference between TreeBLOSSIM estimate and PhotoMARVL measurement of number of clusters per metre in each zone.

Plot / Treatment: (final stocking / age of thinning)	Zone 1	Zone 2
13/24 (unthinned)	-0.01	-0.95**
15/21 (100 / 11)	0.15	-0.67*
9/22 (200 / 11)	0.12*	-0.69**
10/23 (400 / 11)	0.30**	-0.81**
14/25 (100 / 14)	-0.04	-0.87**
11/26 (200 / 14)	-0.20*	-1.16**
12/27 (400 / 14)	0.04	-1.00**

Notes: Means that are significant at $p < 0.05$ are marked with *.
Means that are significant at $p < 0.01$ are marked with **.

DISCUSSION

PhotoMARVL is a non-destructive photogrammetric technique for measuring tree dimensions. It is considered to be an ideal tool for determining how well TreeBLOSSIM (an individual tree stem and branch growth model) can predict branch growth for different thinning regimes.

This report completes the comparison of TreeBLOSSIM predictions with PhotoMARVL data for the 1975 final crop stocking trials (see also SGMC Report Nos. 110 and 116).

<u>Eyrewell</u>

PhotoMARVL images were collected for 35 trees from the final crop stocking trials at Eyrewell (CY597), PSP measurements of tree DBH at age 14 years were imported into TreeBLOSSIM and the trees grown forward to age 26 years (the tree age when the PhotoMARVL images were collected).

Tree DBH was measured using a tape at the same time as the PhotoMARVL images were collected. TreeBLOSSIM tended to overpredict DBH, particularly for the smaller trees.

TreeBLOSSIM prediction for the zone mean of the diameter of the largest branch in a cluster was within 2 cm of the actual mean for all but 3 zones out of 70. However the zone variance, predicted by TreeBLOSSIM was usually larger than observed. This also occurred in the Woodhill replicate (see SGMC report 116). Both these sites have light branching suggesting that the variance is lower for such sites.

TreeBLOSSIM predictions of the number of branch clusters per metre below 9 m were reasonable, but TreeBLOSSIM tended to overpredict the number of branch clusters above 9 m. This trend has been noted in the other studies (see SGMC Report Nos. 110 and 116).

<u>1975 trials in general</u>

Considering the results from the four trials (Woodhill, Kaingaroa, Golden Downs and Eyrewell):

- Prediction of the mean value (averaged over several metres) for diameter of largest branch in a cluster is realistic.
- The following components of the branch model warrant further investigation:
    - Prediction of number of branch clusters in an annual shoot
    - Variability in diameter of the largest branch in a cluster

These points will be considered when revising the TreeBLOSSIM branch functions.

REFERENCES

Stand Growth Modelling Cooperative Reports.

93: Grace, J.C.; Brownlie, R.K. 2000: Suitability of PhotoMARVL for measuring crown structure.

99: Grace, J.C.; Brownlie, R.K. 2001: Use of PhotoMARVL to determine response to thinning: Further results from Experiment RO2098.

104: Grace, J.C.; Brownlie, R.K. 2001: Branch response to thinning in Experiment CY597, results from using PhotoMARVL.

108: Grace, J.C.; Pont, D. 2001: Branch functions within TreeBLOSSIM – Version 1.1.

110: Grace, J.C. 2001: Sensitivity analysis of TreeBLOSSIM: PhotoMARVL trees from Experiment RO2098.

112: Grace, J.C.; Brownlie, R.K. 2002: Branch response to thinning in Woodhill (AK1056) and Golden Downs (NN529) – PhotoMARVL data.

113: Pont, D.; Grace, J.C.; Gordon, A.; Shula, B. 2002: A guide to using TreeBLOSSIM Version 1.2.

116: Grace, J.C.; Brownlie, R.K. 2003: Sensitivity analysis of TreeBLOSSIM: PhotoMARVL trees from Experiment AK 1056 (Woodhill) and NN529/1 (Golden Downs).

Other reports/ papers.

Firth, J.G.; Brownlie, R.K.; Carson, W.W. 2000: Accurate stem measurements, key to new image-based system. New Zealand Journal of Forestry 45 (2): 25-29.

APPENDIX 1: Eyrewell (CY597) - Diameter of largest branch in a cluster - *PhotoMARVL* measurements and TreeBLOSSIM predictions.

Figure 2. Tree at 10th percentile of DBH in plot thinned to 200 stems/ha at age 11 years

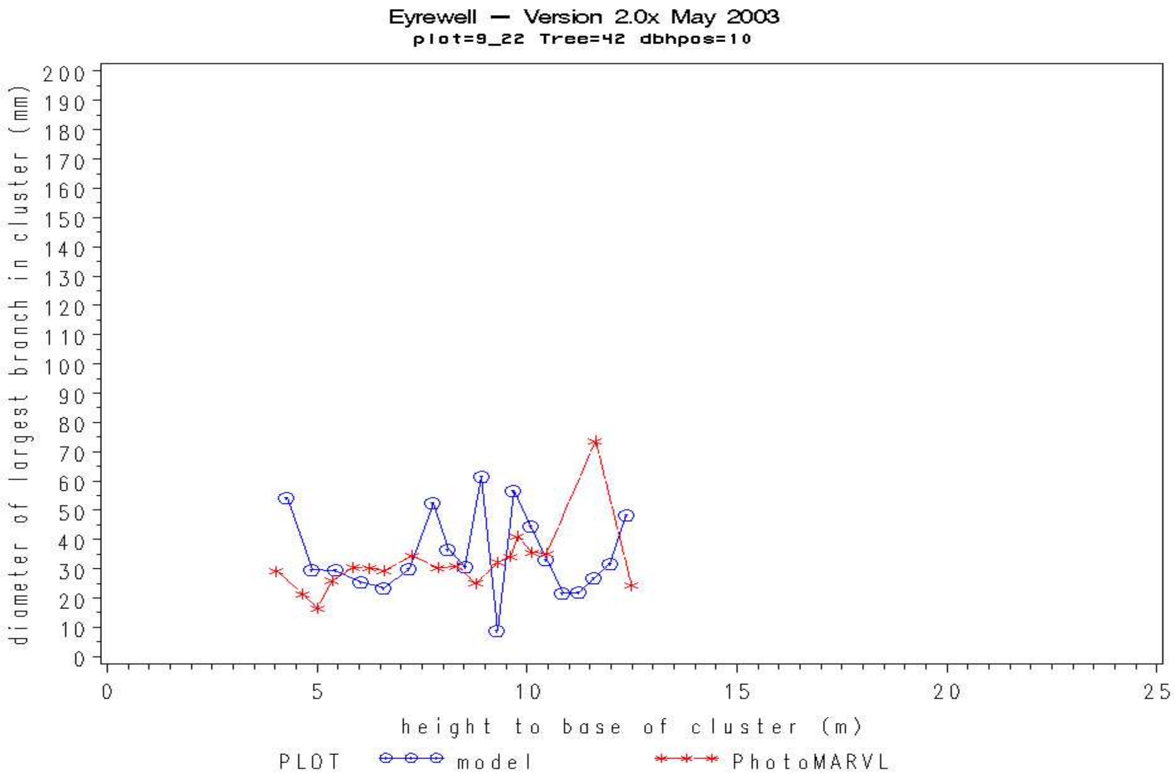


Figure 3. Tree at 40th percentile of DBH distribution in plot thinned to 200 stems/ha at age 11 years

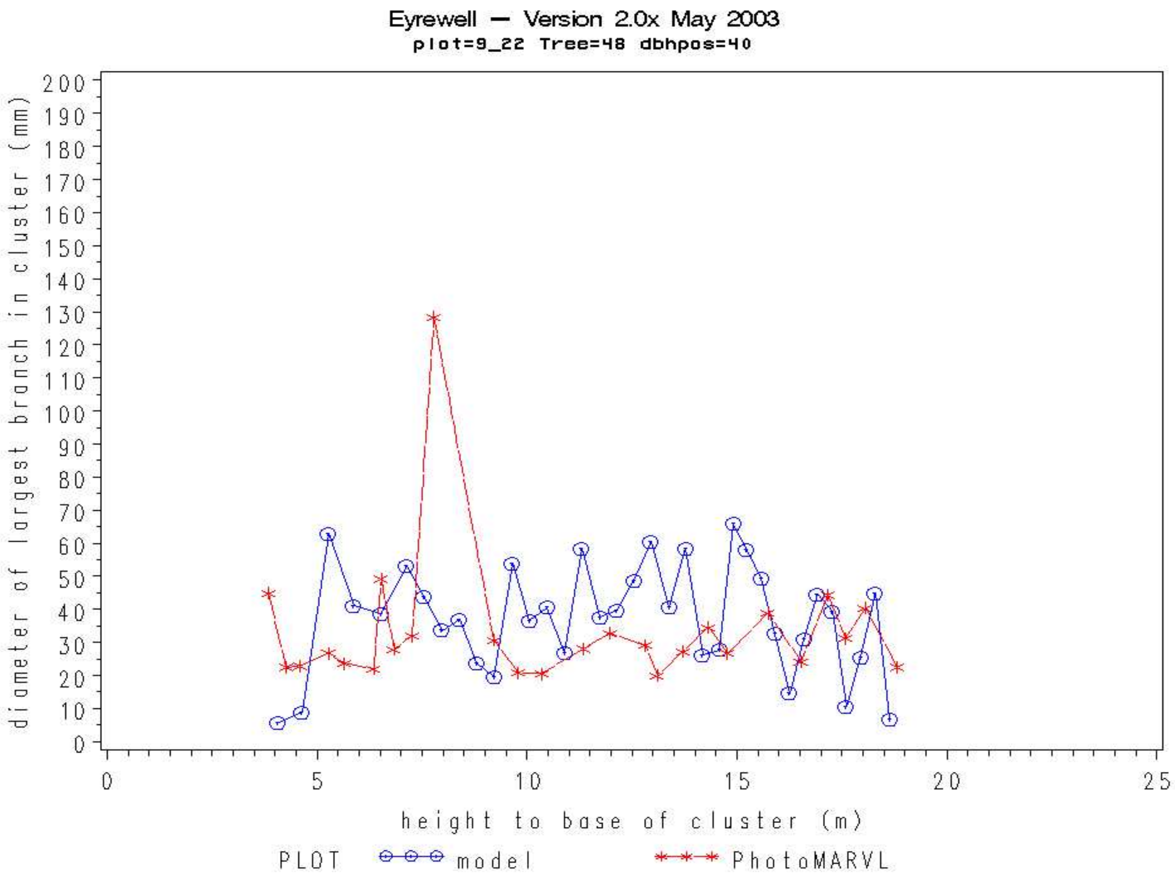


Figure 4. Tree at 70th percentile of DBH distribution in plot thinned to 200 stems/ha at age 11 years

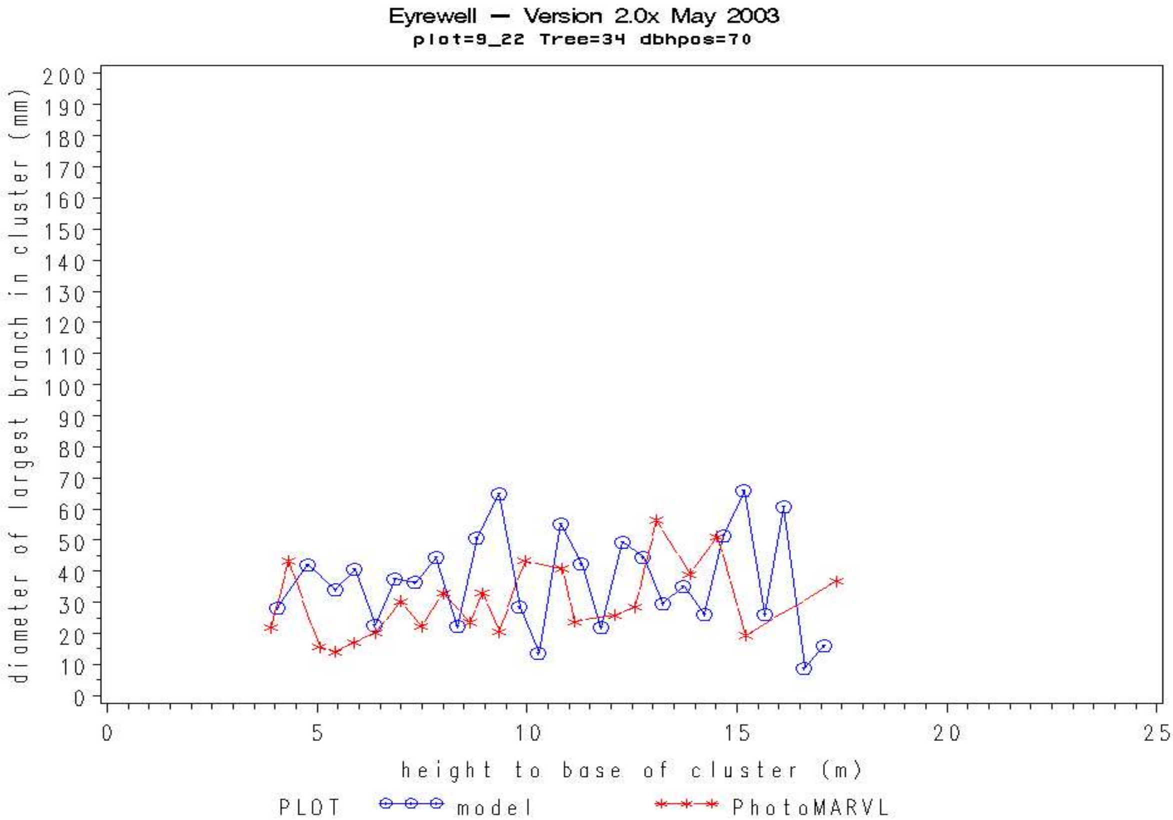


Figure 5. Tree at 90th percentile of DBH distribution in plot thinned to 200 stems/ha at age 11 years

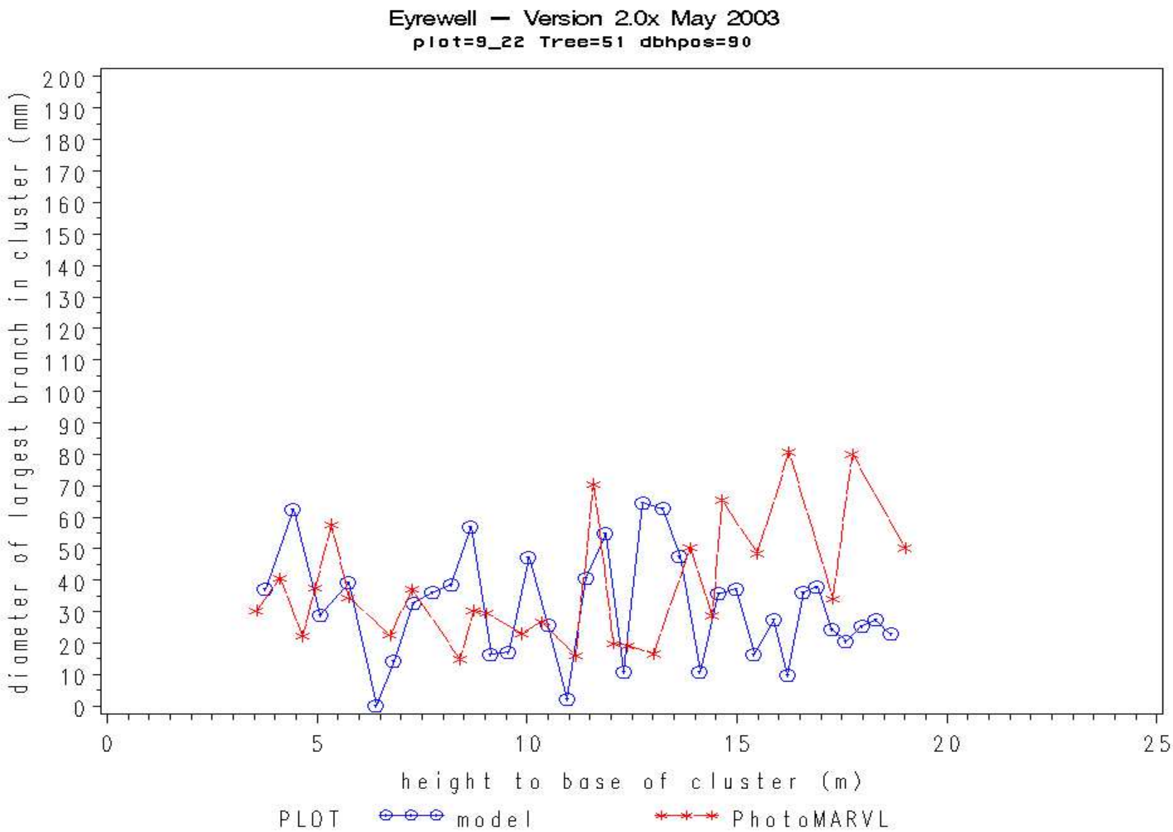


Figure 6. Tree at 100th percentile of DBH distribution in plot thinned to 200 stems/ha at age 11 years

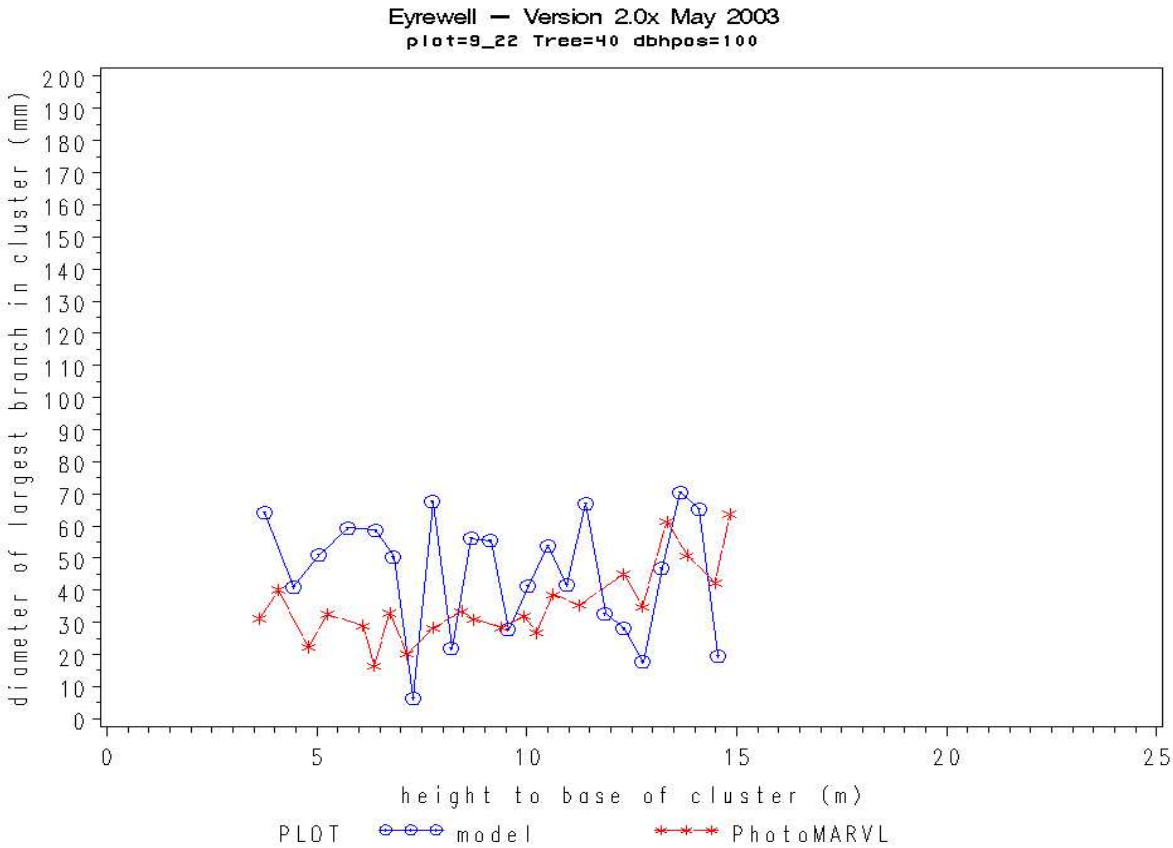


Figure 7. Tree at 10th percentile of DBH distribution in plot thinned to 400 stems/ha at age 11 years

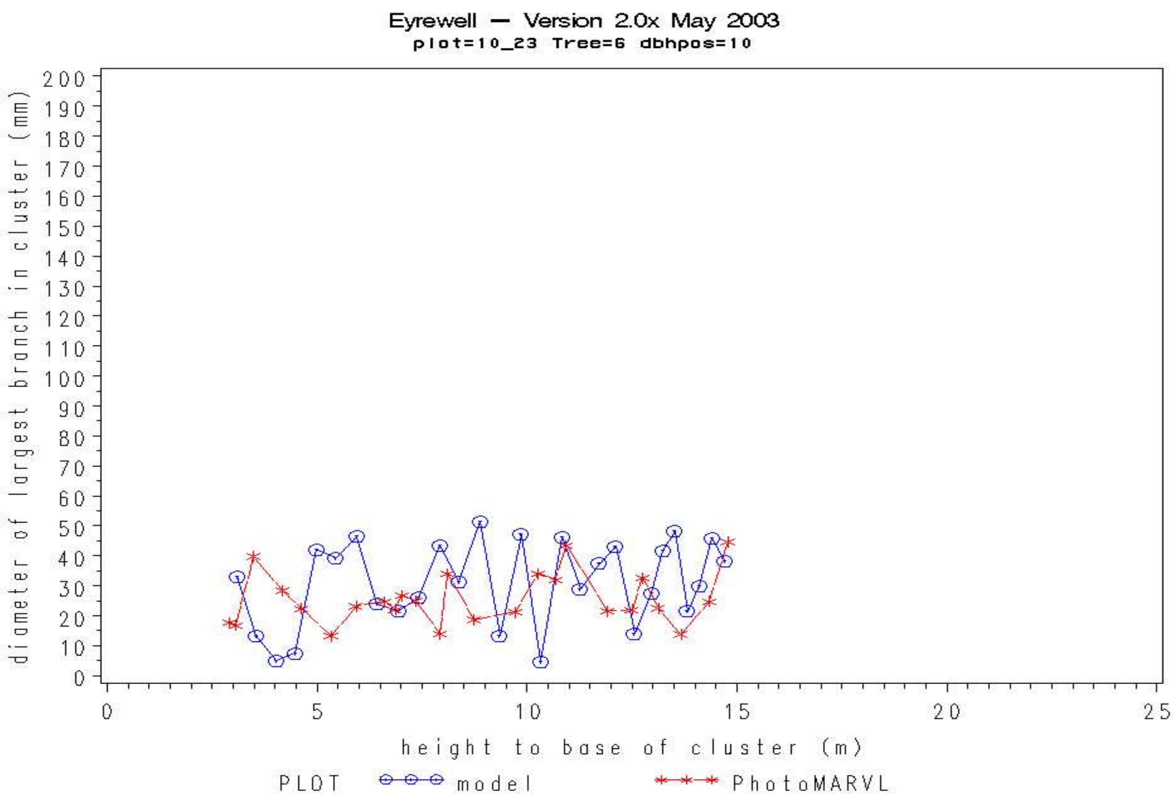


Figure 8. Tree at 40th percentile of DBH distribution in plot thinned to 400 stems/ha at age 11 years

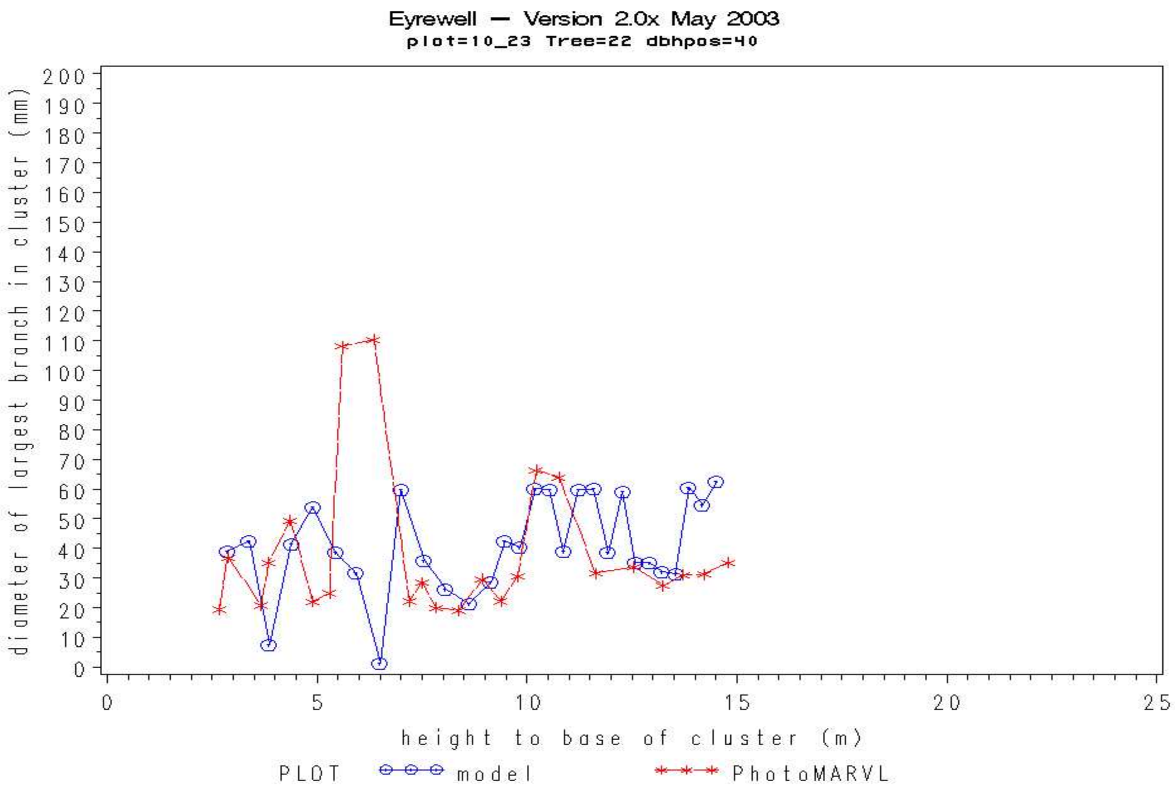


Figure 9. Tree at 70th percentile of DBH distribution in plot thinned to 400 stems/ha at age 11 years

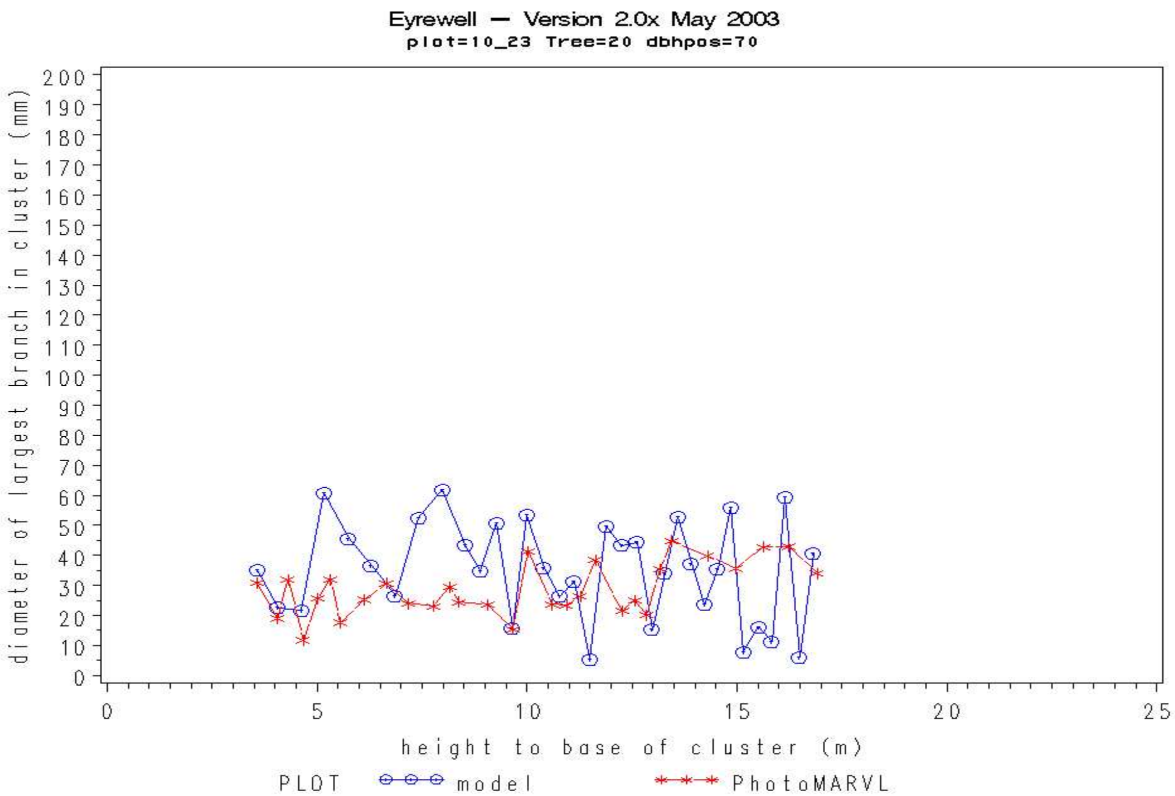


Figure 10. Tree at 90th percentile of DBH distribution in plot thinned to 400 stems/ha at age 11 years

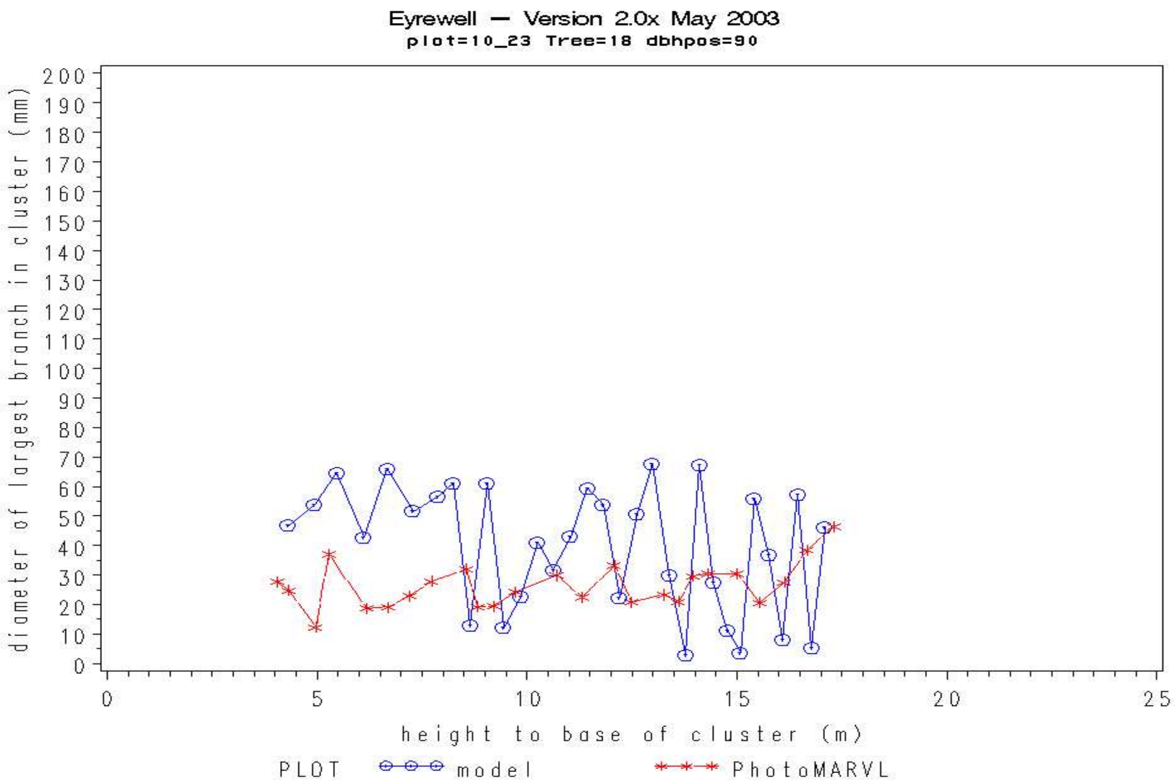


Figure 11. Tree at 100th percentile of DBH distribution in plot thinned to 400 stems/ha at age 11 years

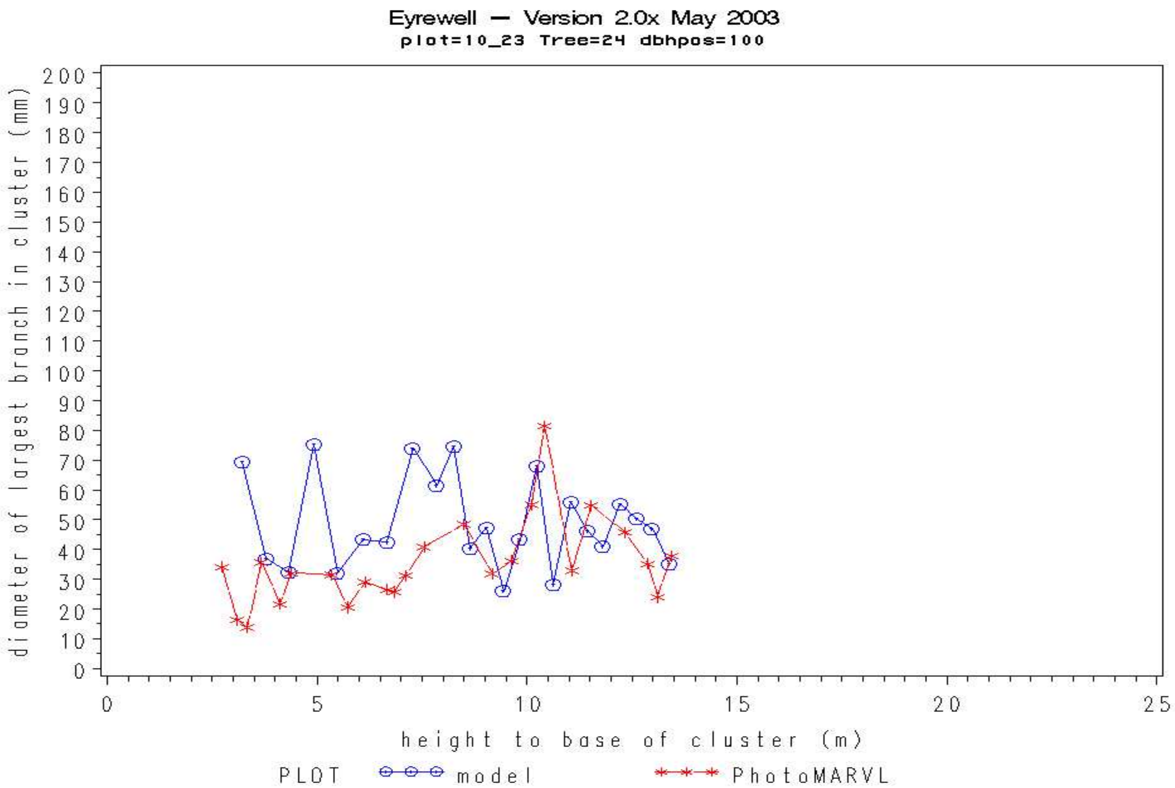


Figure 12. Tree at 10th percentile of DBH distribution in plot thinned to 200 stems/ha at age 14 years

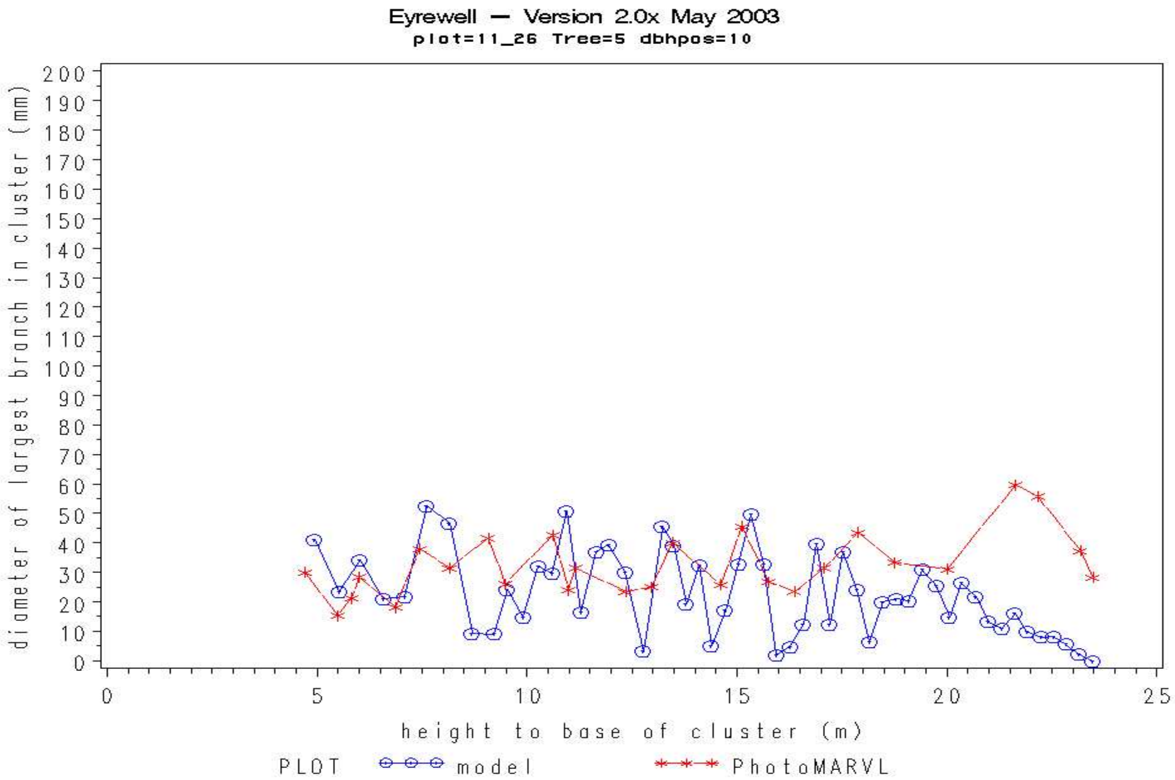


Figure 13. Tree at 40th percentile of DBH distribution in plot thinned to 200 stems/ha at age 14 years

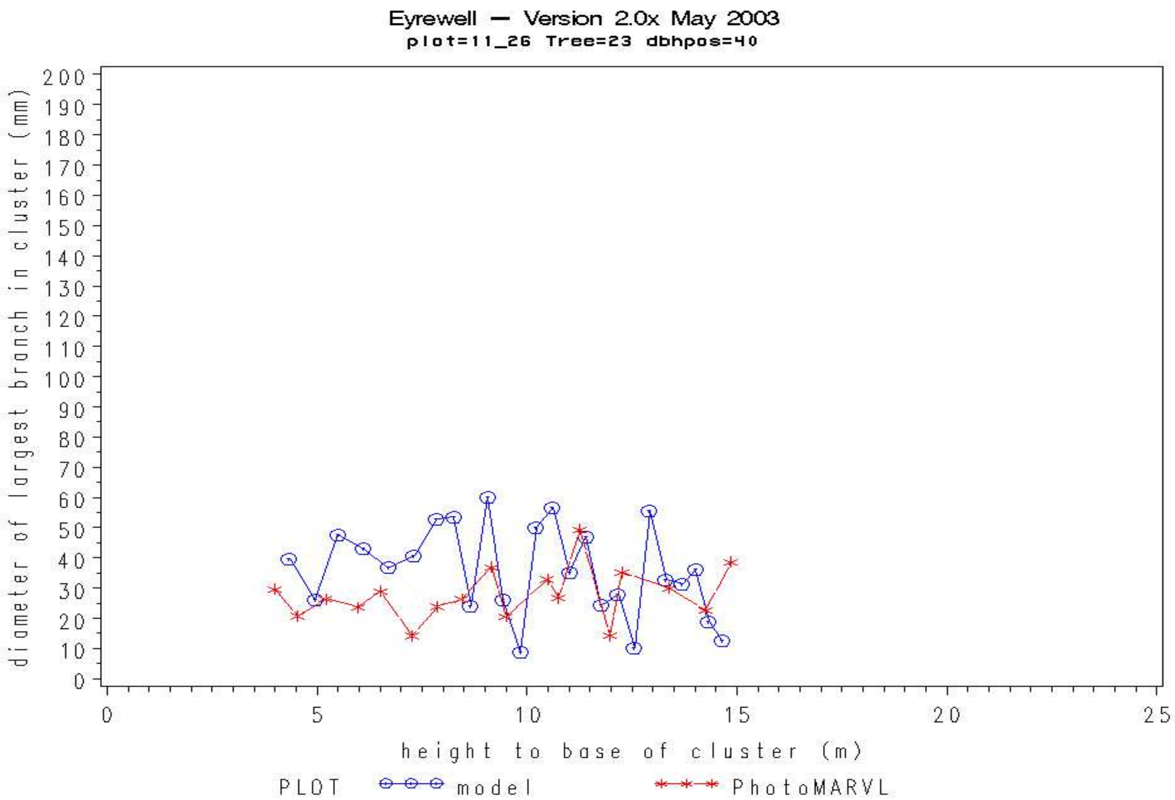


Figure 14. Tree at 70th percentile of DBH distribution in plot thinned to 200 stems/ha at age 14 years

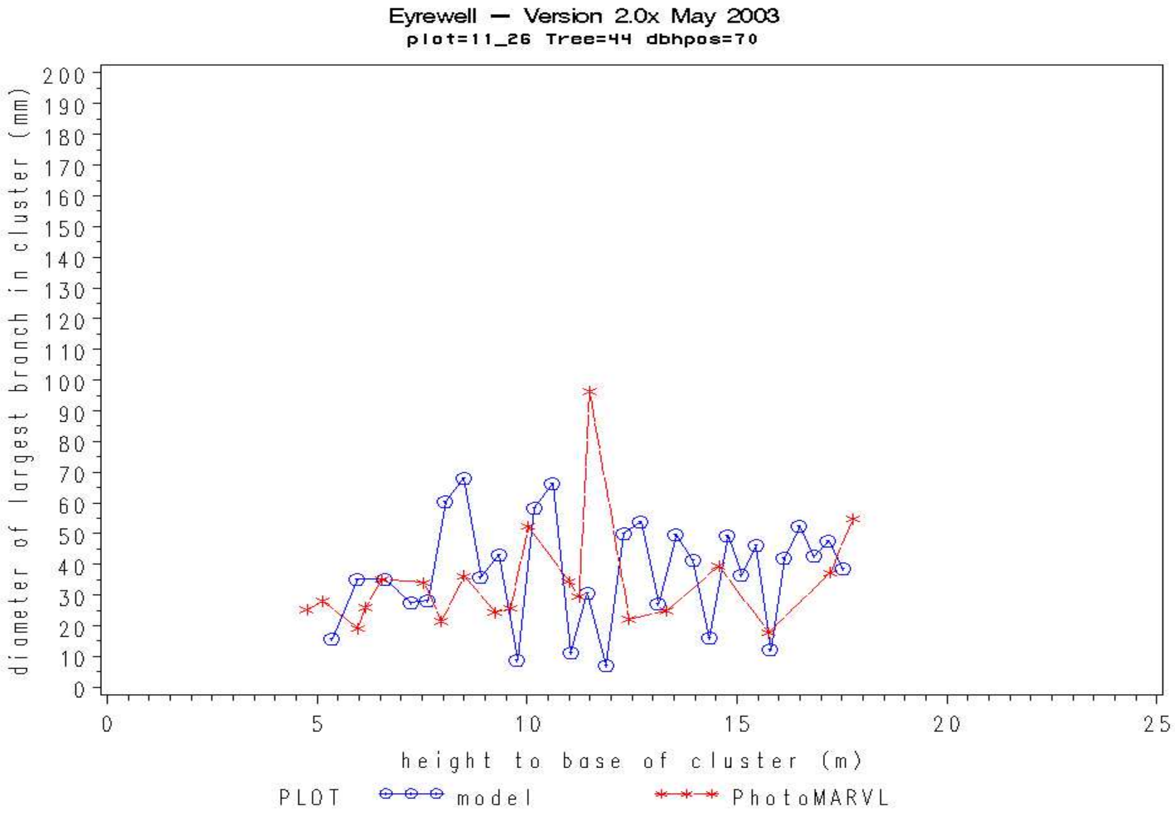


Figure 15. Tree at 90th percentile of DBH distribution in plot thinned to 200 stems/ha at age 14 years

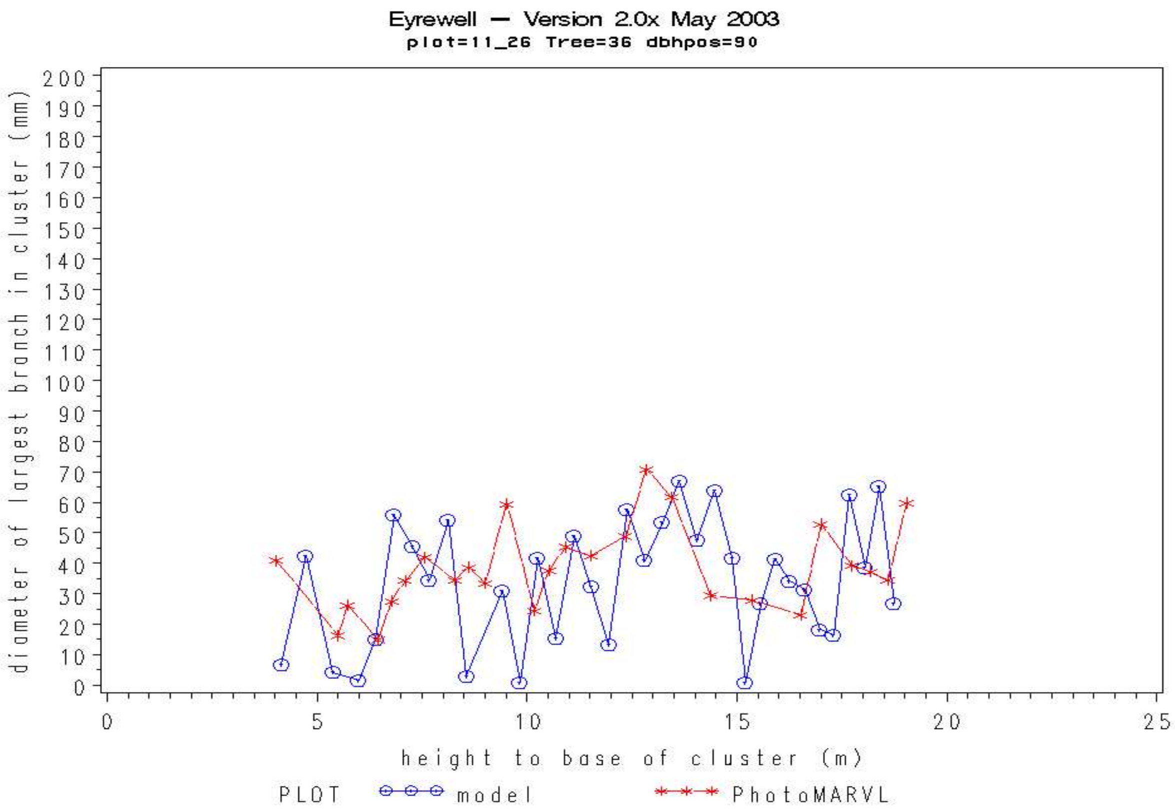


Figure 16. Tree at 100th percentile of DBH distribution in plot thinned to 200 stems/ha at age 14 years

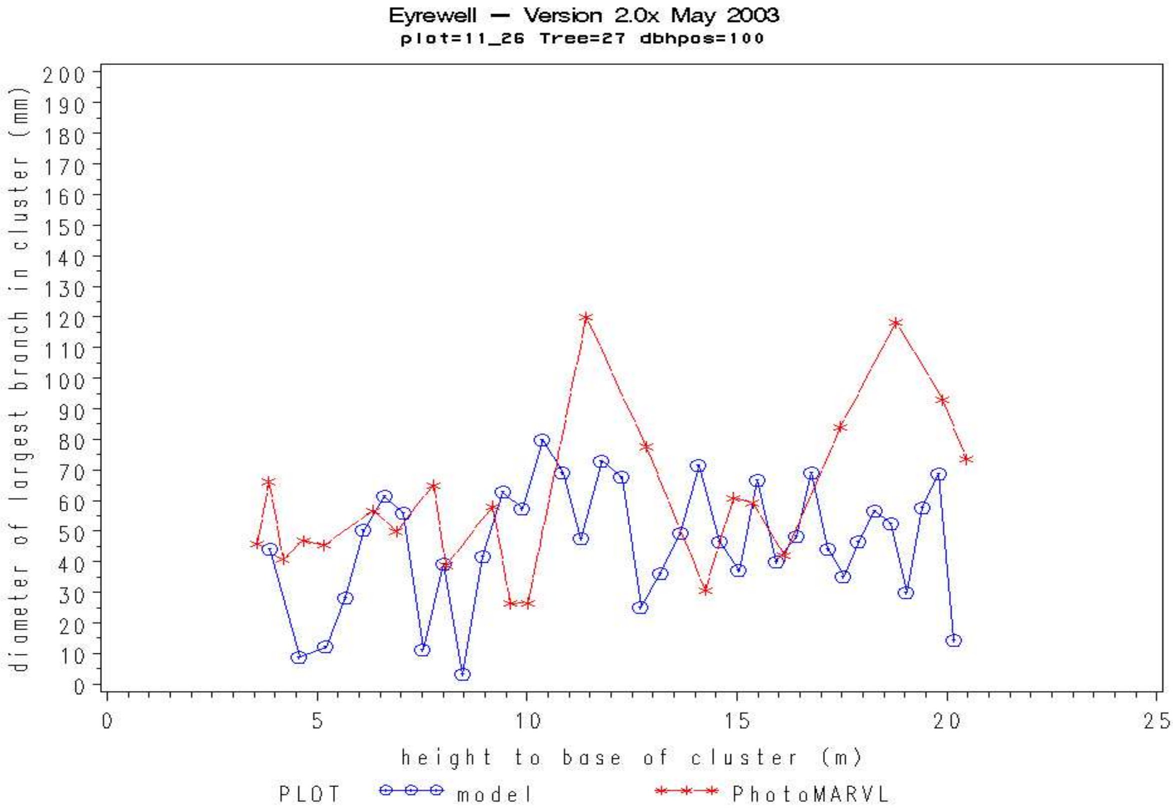


Figure 17. Tree at 10th percentile of DBH distribution in plot thinned to 400 stems/ha at age 14 years

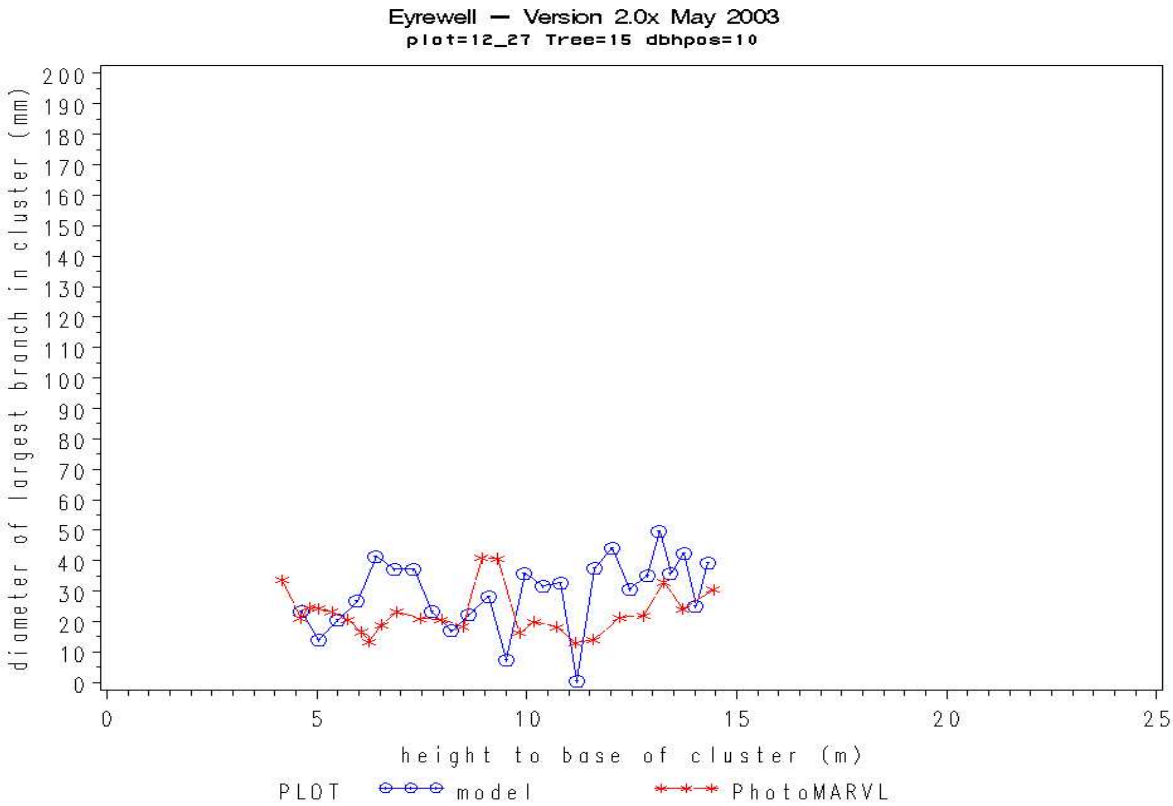


Figure 18. Tree at 40th percentile of DBH distribution in plot thinned to 400 stems/ha at age 14 years

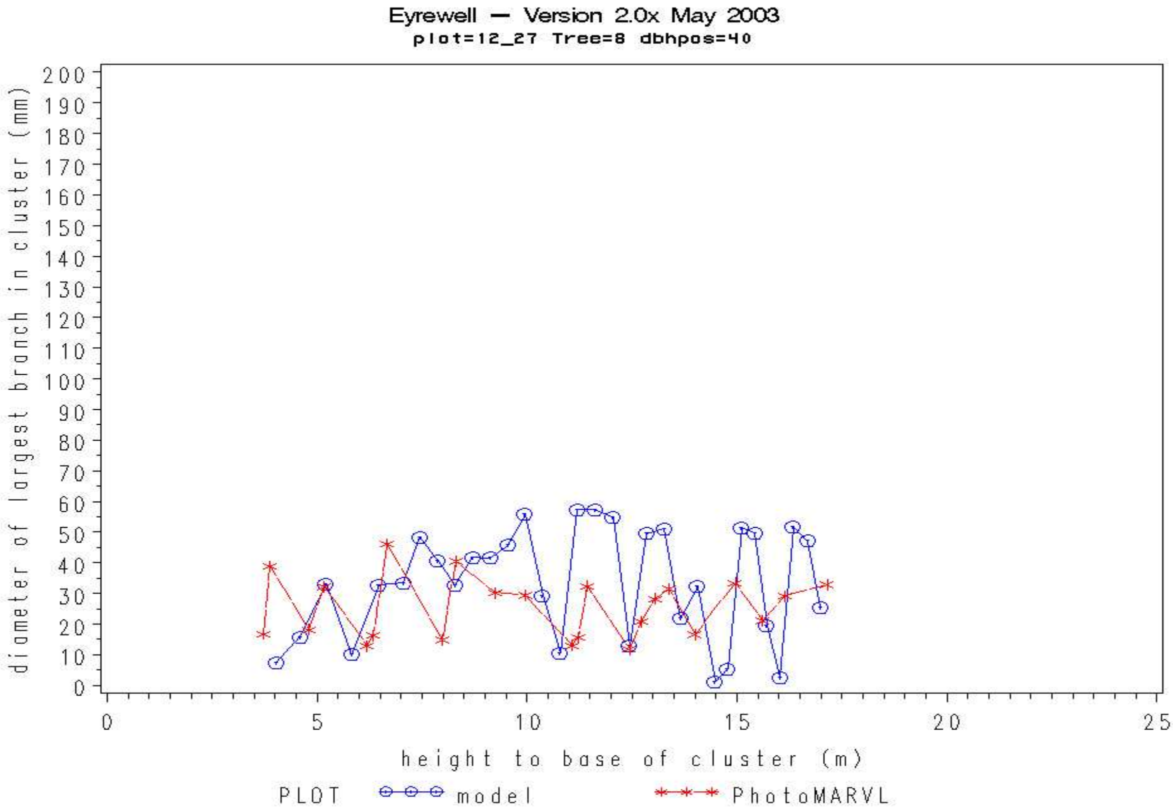


Figure 19. Tree at 70th percentile of DBH distribution in plot thinned to 400 stems/ha at age 14 years

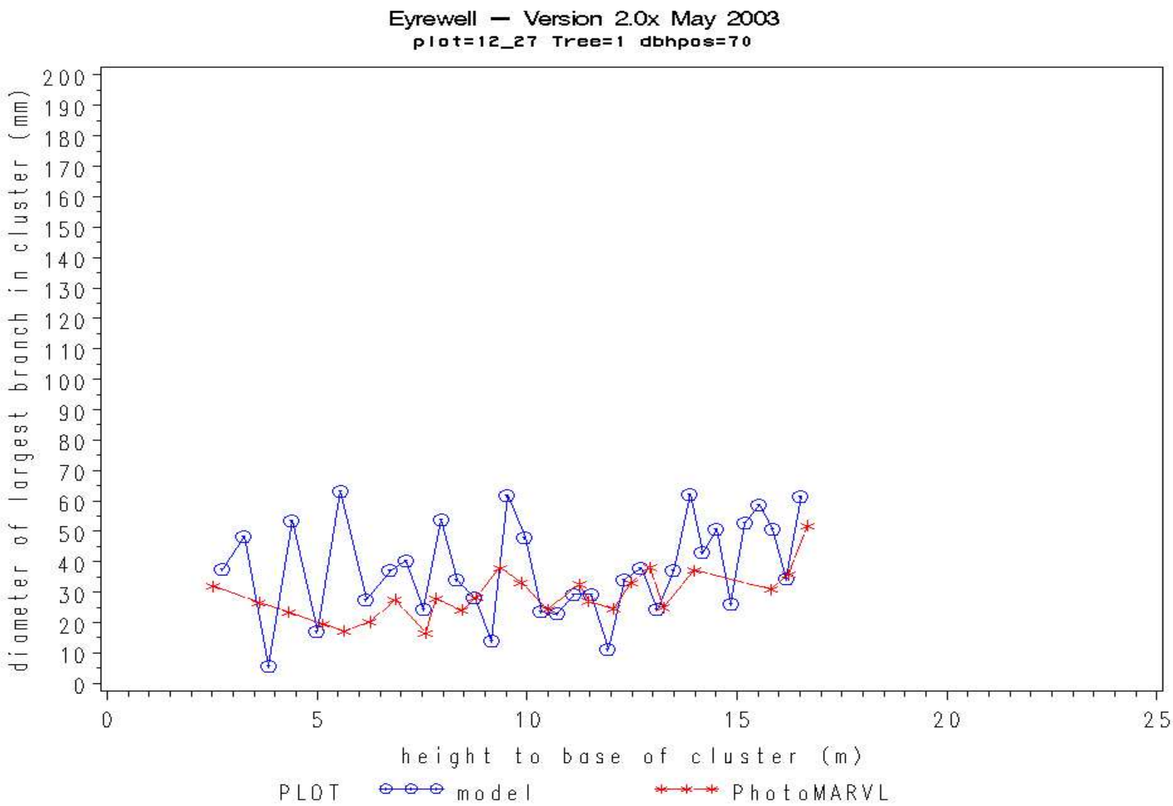


Figure 20. Tree at 90th percentile of DBH distribution in plot thinned to 400 stems/ha at age 14 years

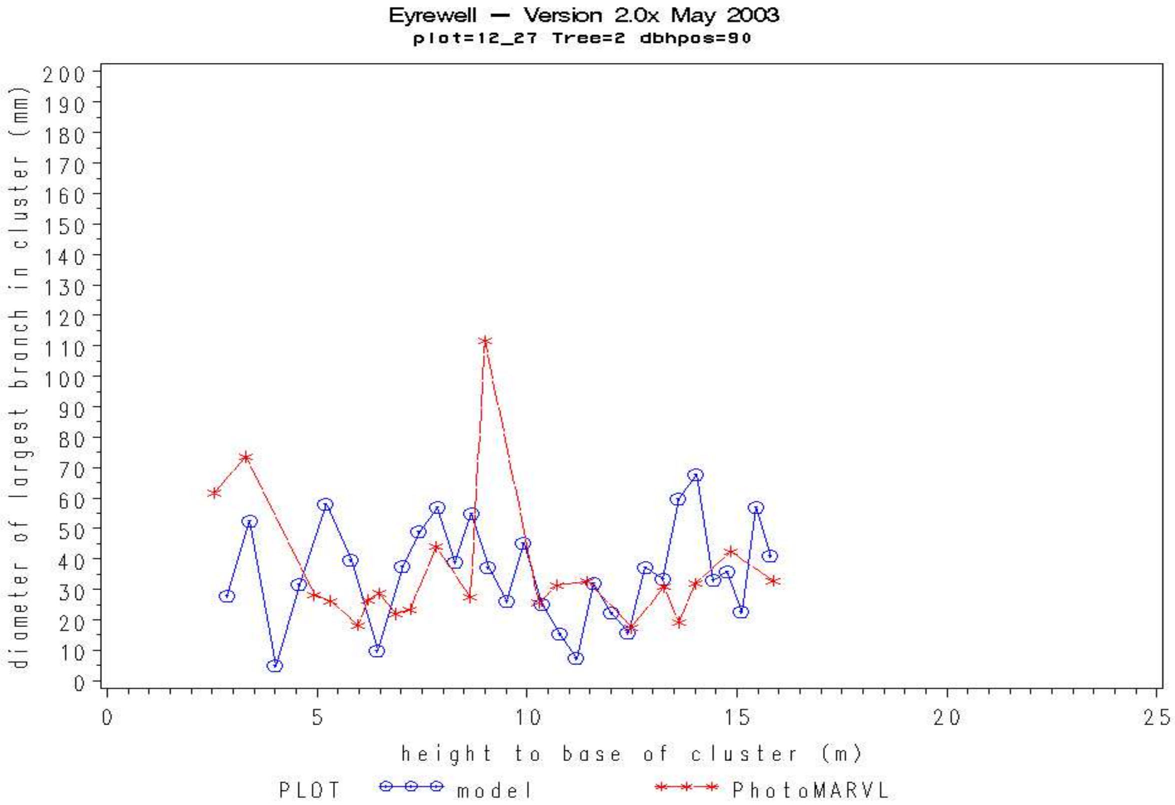


Figure 21. Tree at 100th percentile of DBH distribution in plot thinned to 400 stems/ha at age 14 years

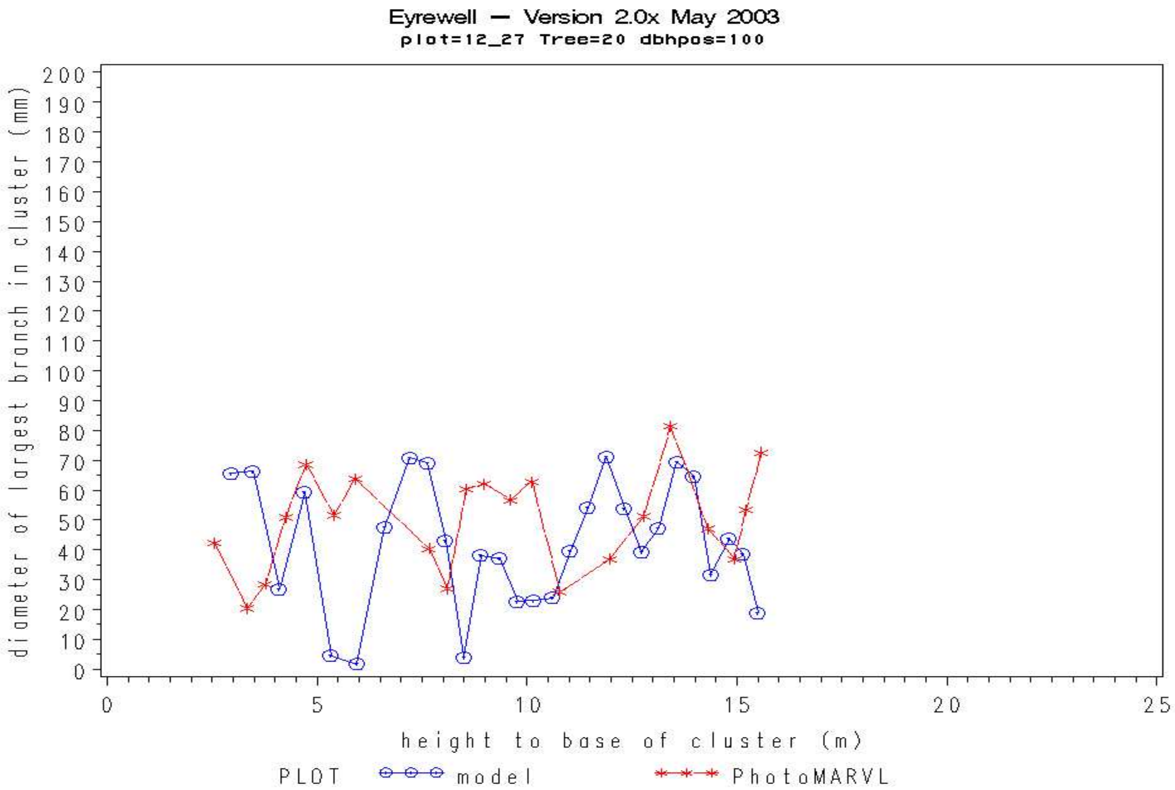


Figure 22. Tree at 10th percentile of DBH distribution in unthinned plot

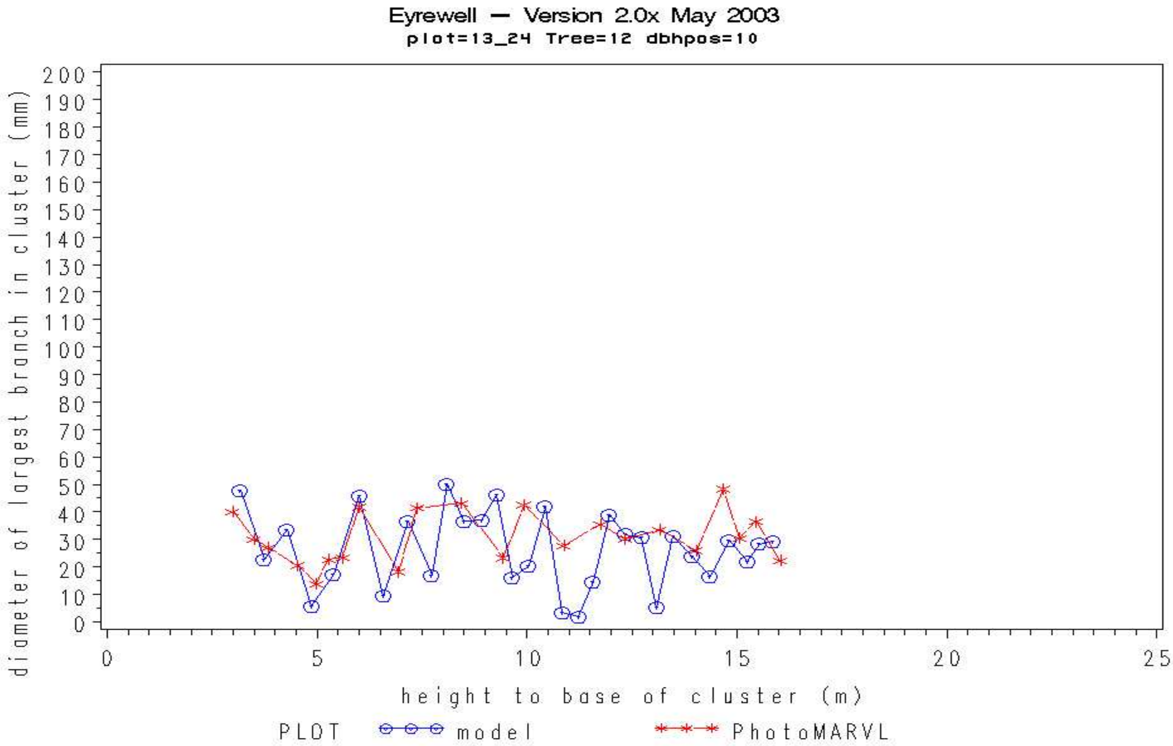


Figure 23. Tree at 40th percentile of DBH distribution in unthinned plot

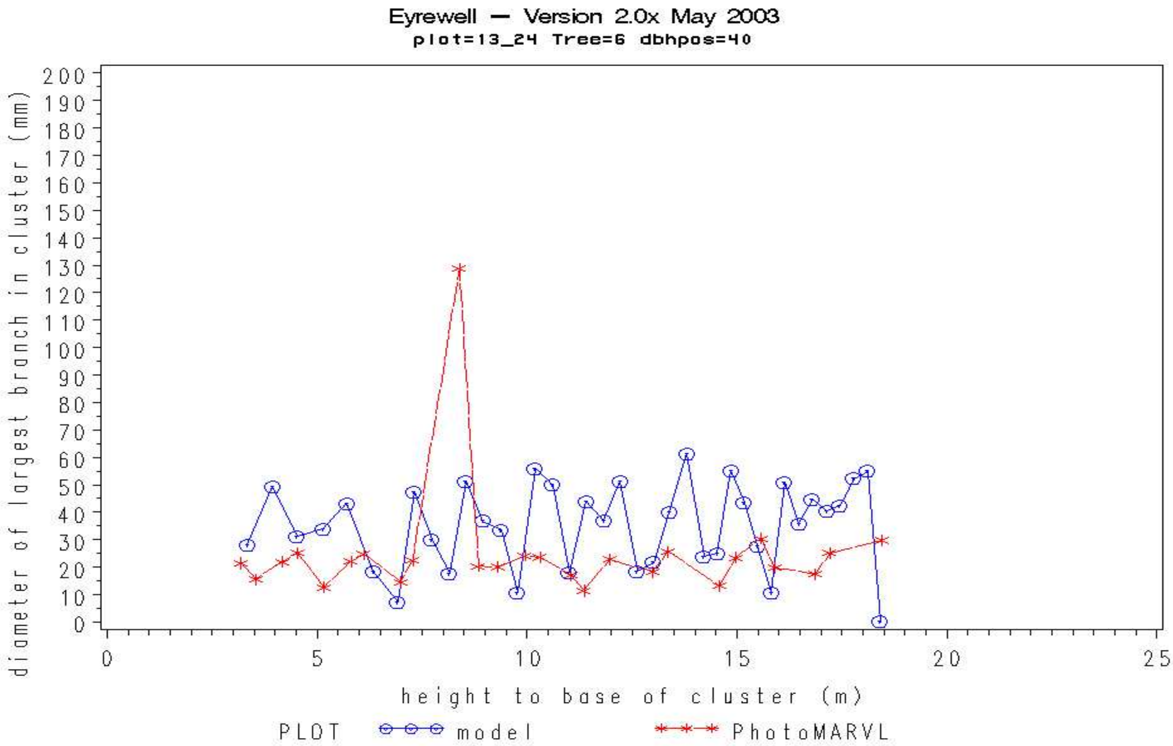


Figure 24. Tree at 70th percentile of DBH distribution in unthinned plot

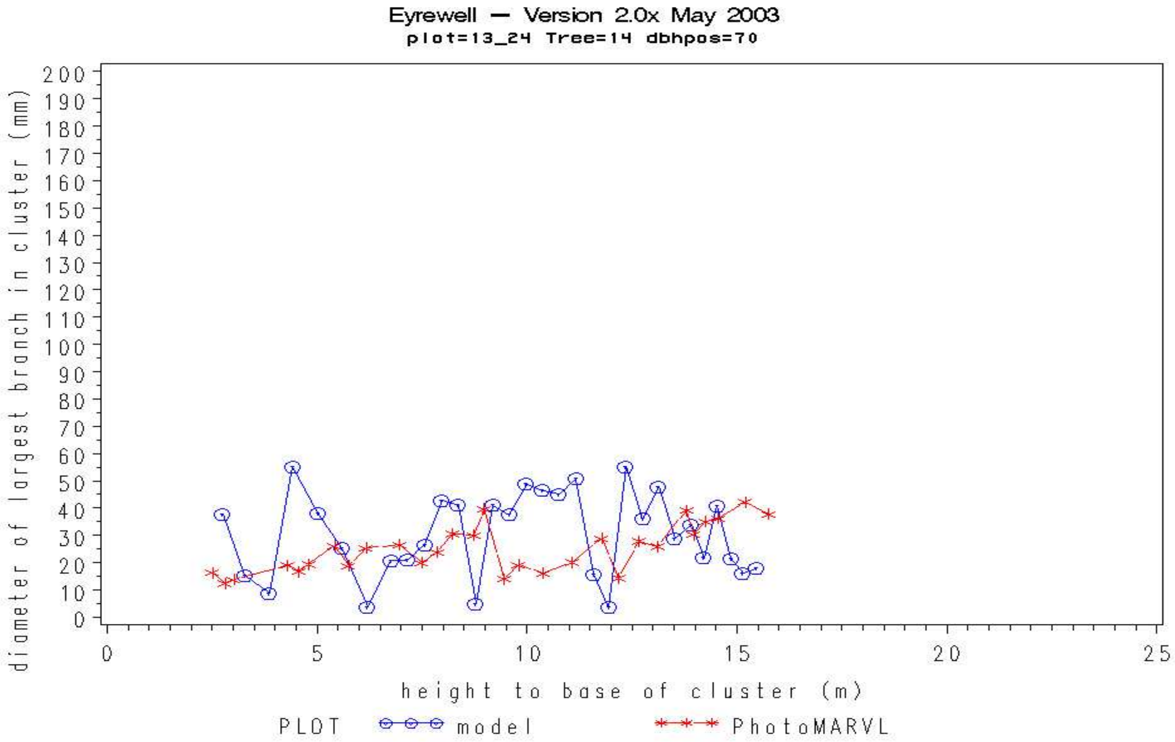


Figure 25. Tree at 90th percentile of DBH distribution in unthinned plot

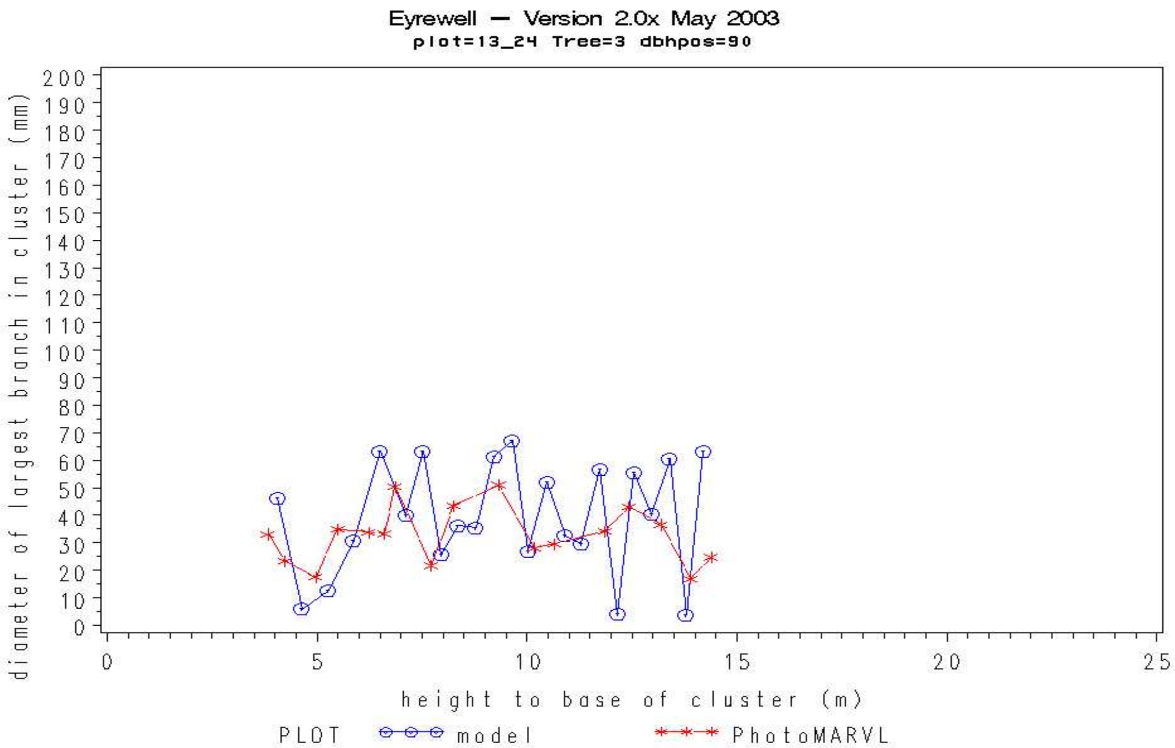


Figure 26. Tree at 100th percentile of DBH distribution in unthinned plot

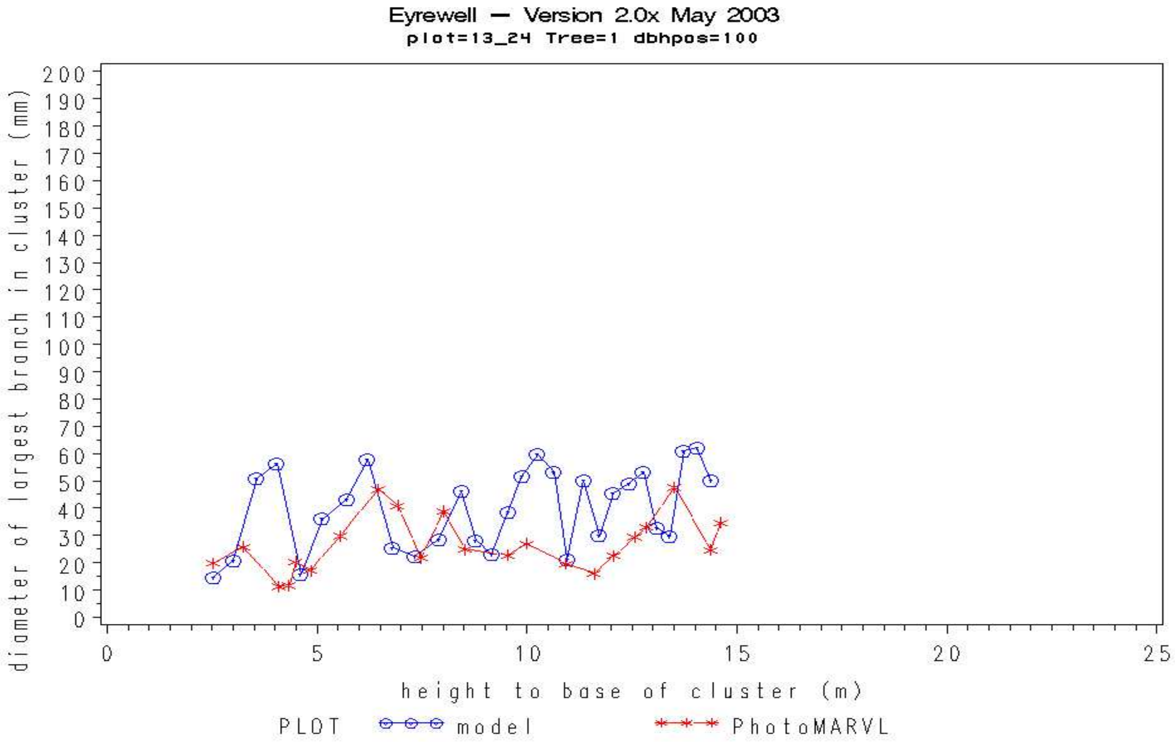


Figure 27. Tree at 10th percentile of DBH distribution in plot thinned to 100 stems/ha at age 14 years

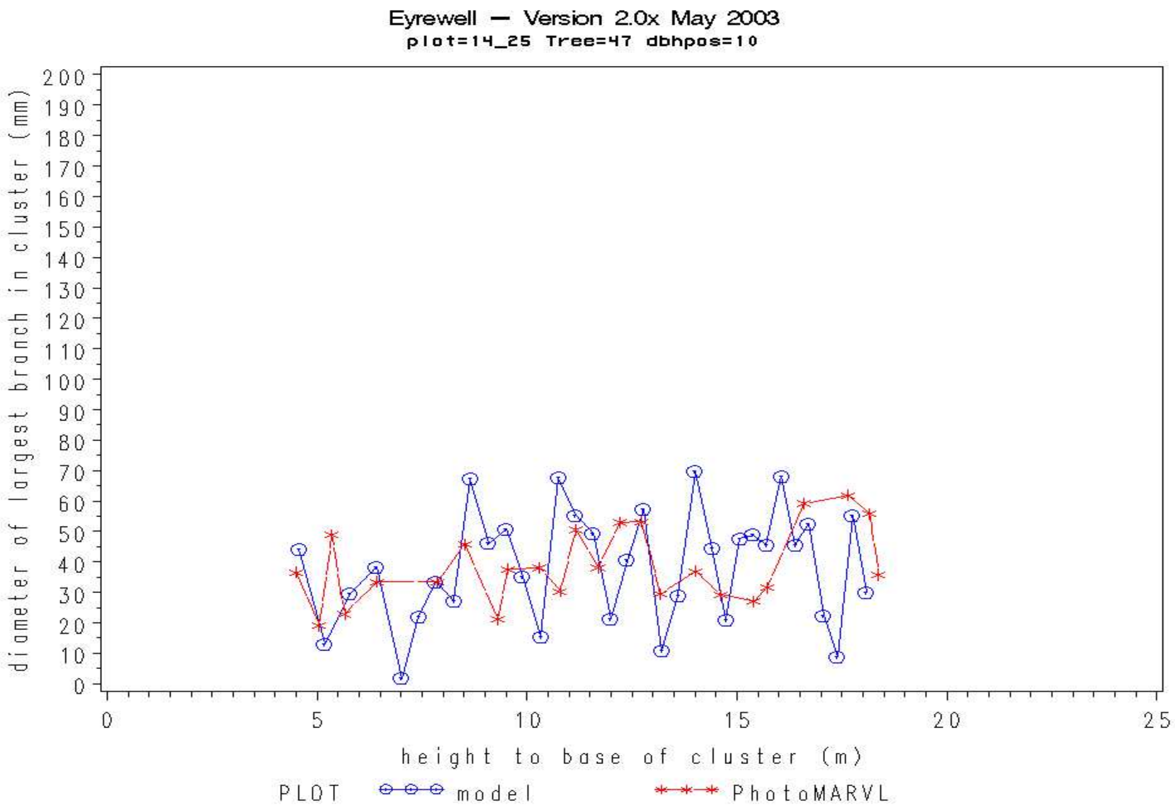


Figure 28. Tree at 40th percentile of DBH distribution in plot thinned to 100 stems/ha at age 14 years

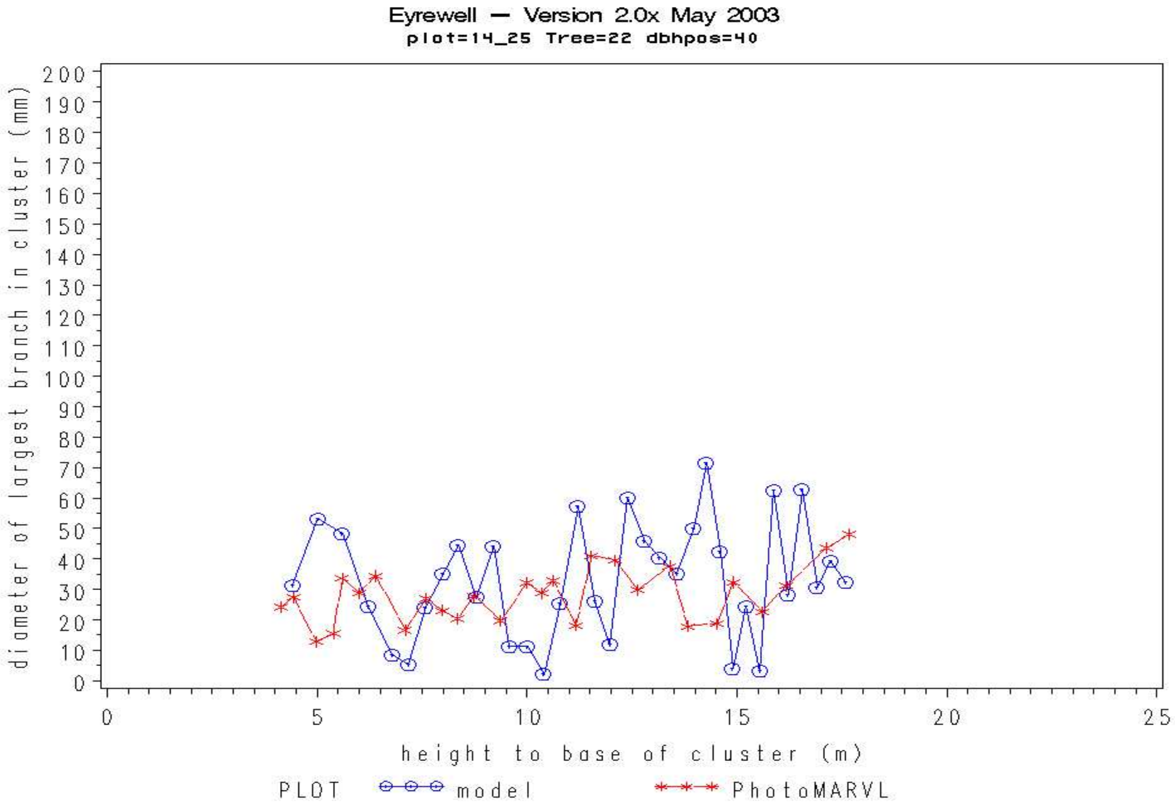


Figure 29. Tree at 70th percentile of DBH distribution in plot thinned to 100 stems/ha at age 14 years

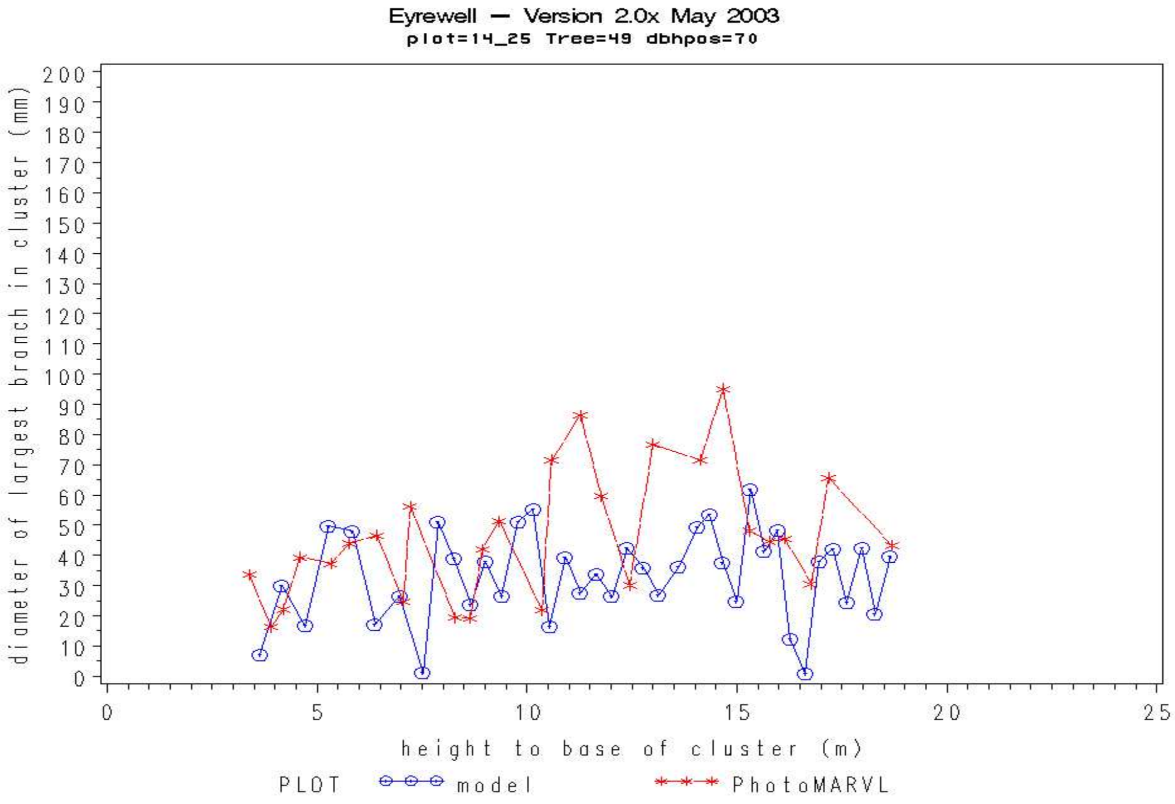


Figure 30. Tree at 90th percentile of DBH distribution in plot thinned to 100 stems/ha at age 14 years

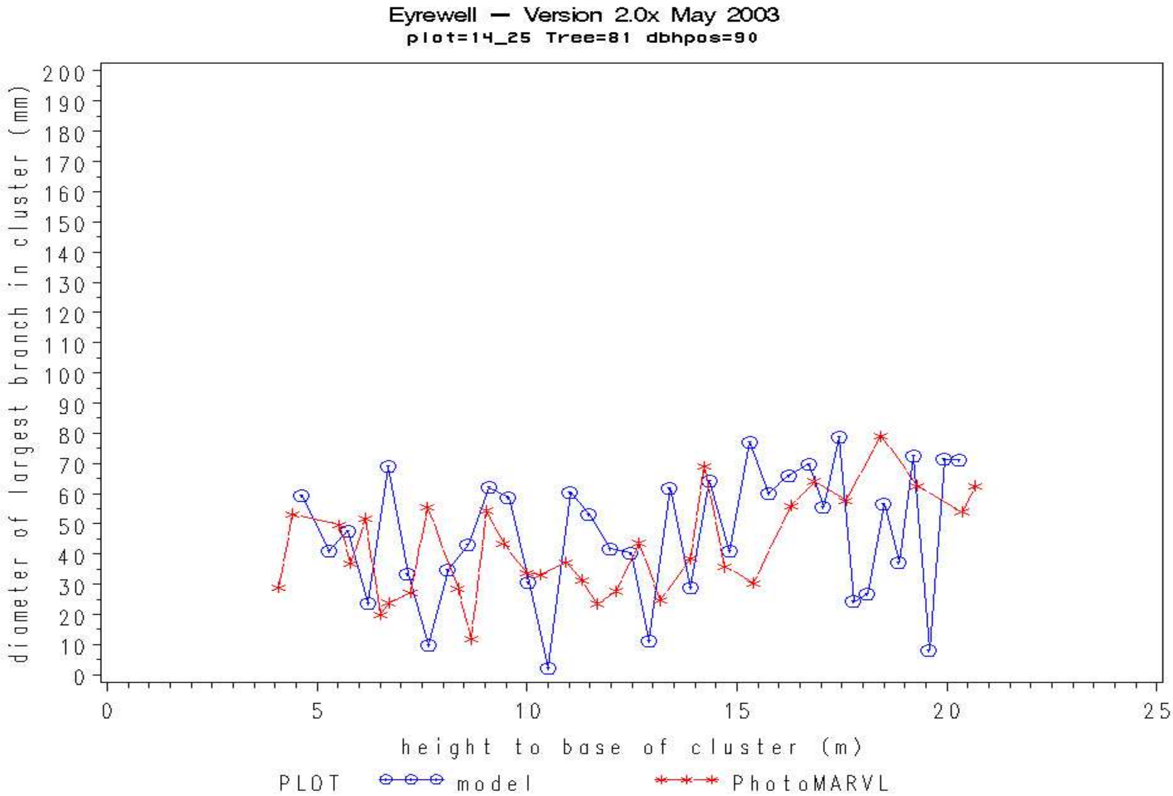


Figure 31. Tree at 100th percentile of DBH distribution in plot thinned to 100 stems/ha at age 14 years

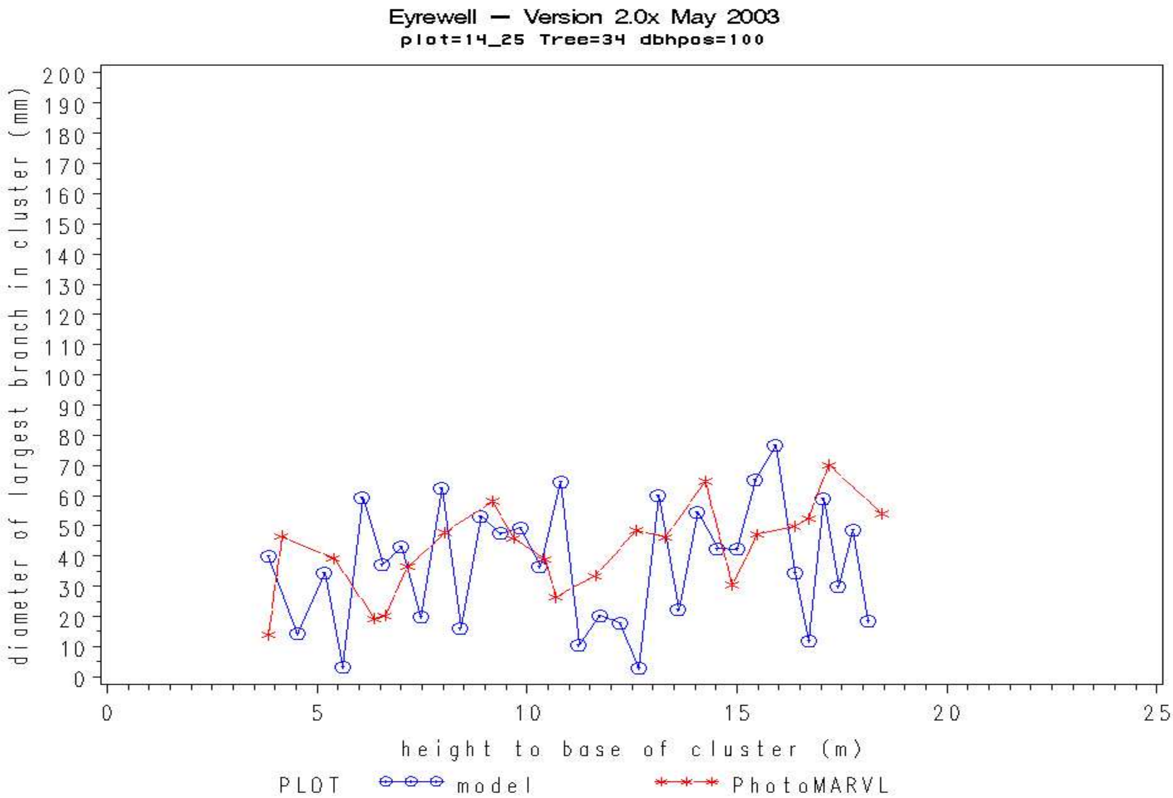


Figure 32. Tree at 10th percentile of DBH distribution in plot thinned to 100 stems/ha at age 11 years

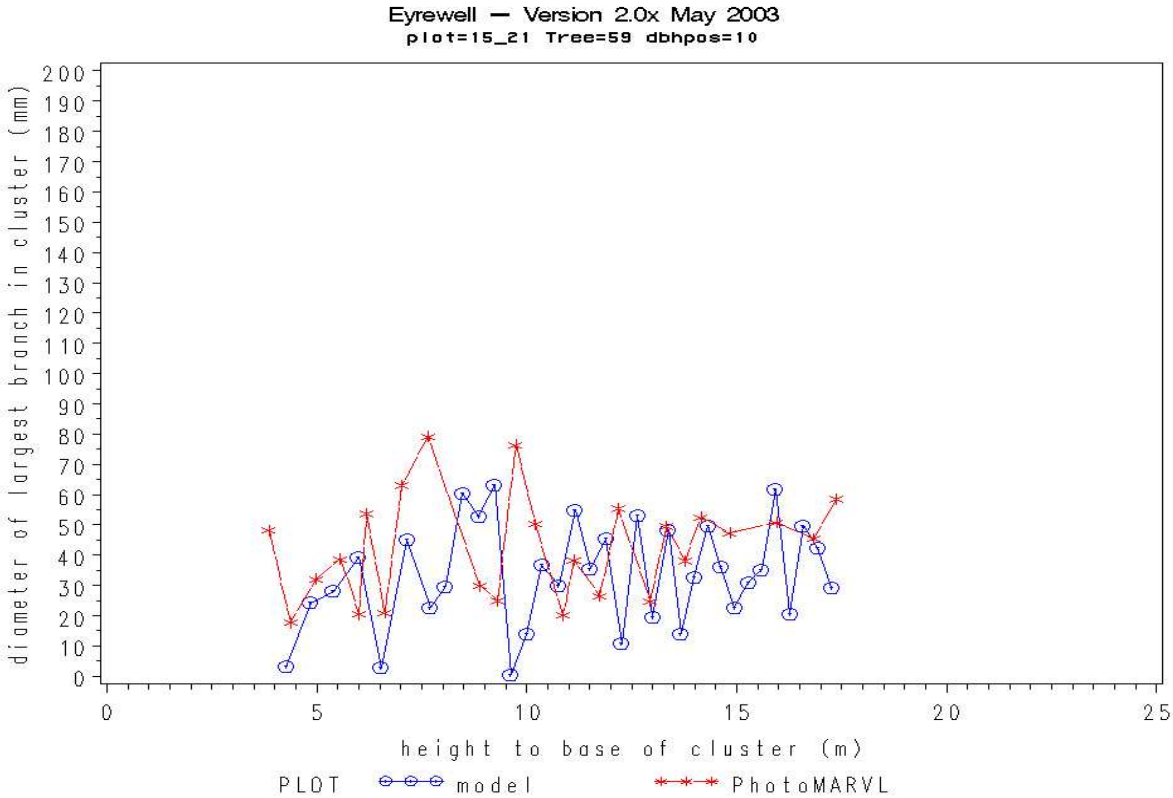


Figure 33. Tree at 40th percentile of DBH distribution in plot thinned to 100 stems/ha at age 11 years

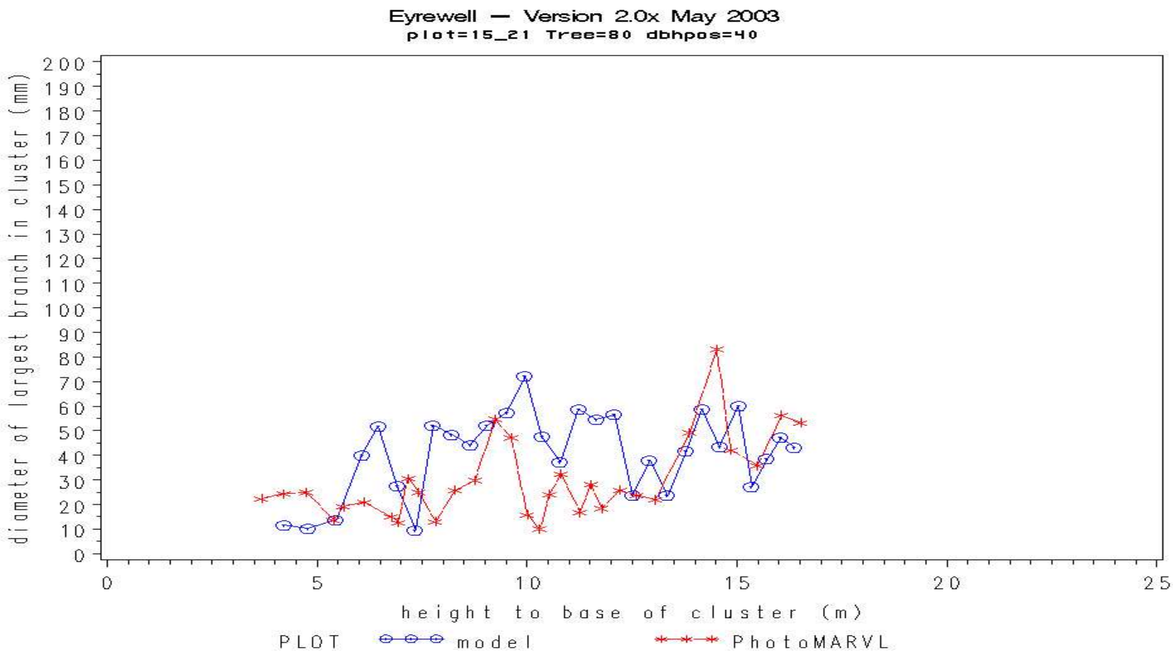


Figure 34. Tree at 70th percentile of DBH distribution in plot thinned to 100 stems/ha at age 11 years

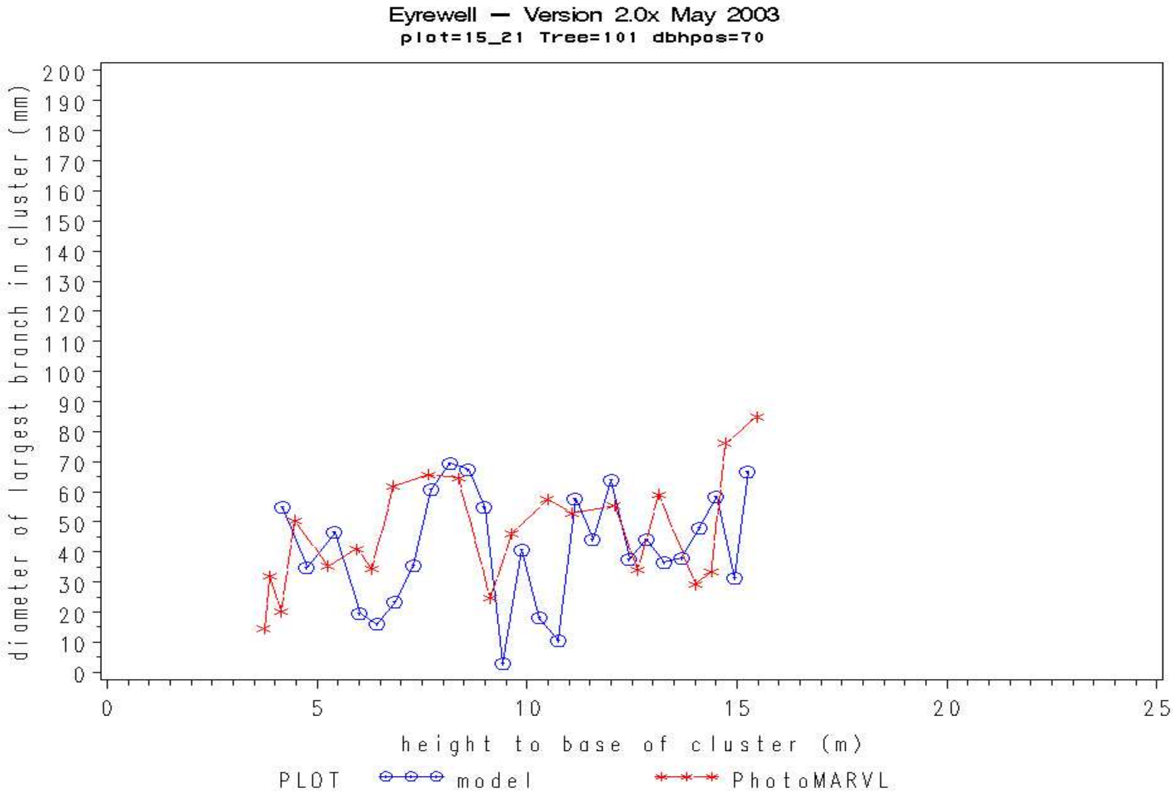


Figure 35. Tree at 90th percentile of DBH distribution in plot thinned to 100 stems/ha at age 11 years

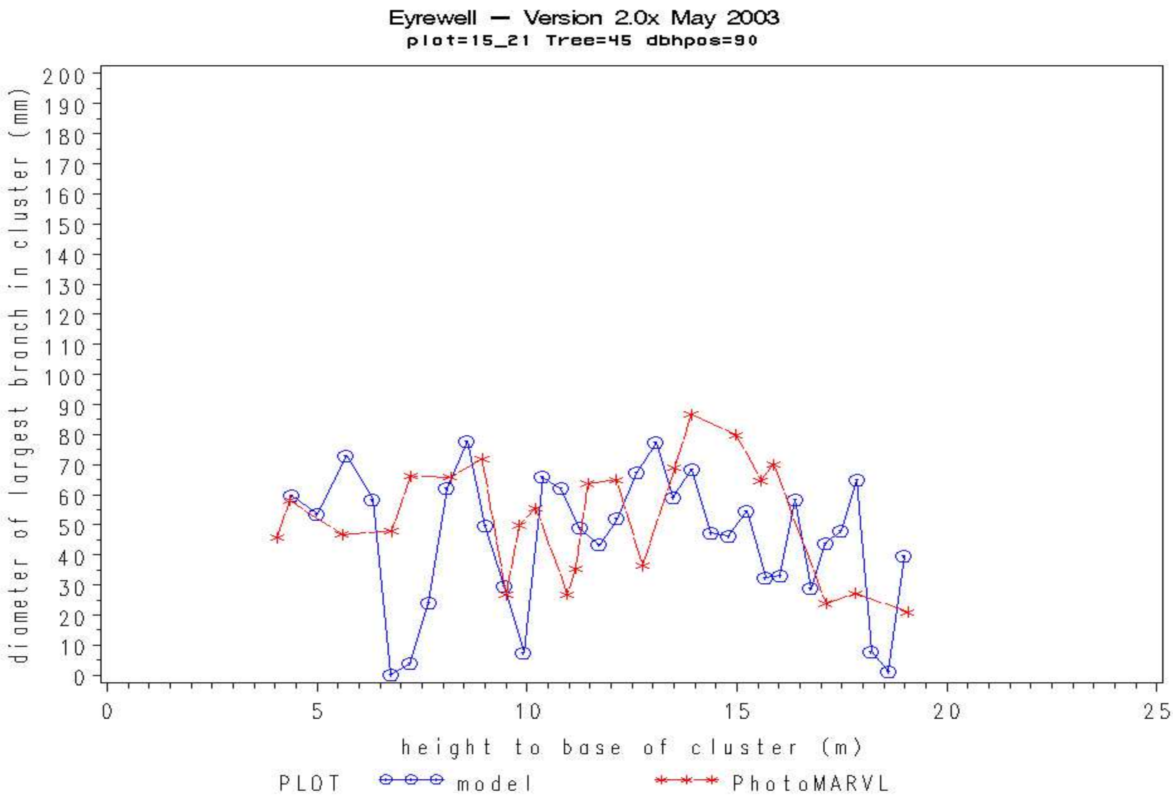


Figure 36. Tree at 100th percentile of DBH distribution in plot thinned to 100 stems/ha at age 11 years